SPECIAL ARTICLE

AERIAL PHOTOGRAPHS, THEIR INTERPRETATION AND SUGGESTED USES IN WILDLIFE MANAGEMENT

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INTRODUCTION

Although experiments in aerial photography date back to the last century, it was not until the first World War that any great advances were made in this field. Following World War I, the United States Coast and Geodetic Survey, the United States Geological Survey and other governmental agencies were quick to realize the possibilities of aerial photography in their work. Improvements were made steadily in film, cameras, airplanes, mapping instruments and techniques until the use of aerial photographs became standard procedure in many fields.

During World War II attention was again focused on the importance of aerial photography in military operations and many refinements were made in techniques. Colonel Paul C. Cullen (1946) stated that over 171,000,000 aerial photographic negatives were made for various military uses by the U. S. Army Air Forces during the second World War.

It was during the writer's experience as a photo interpreter in the intelligence detachments of the 8th and 9th Army Air Forces (1942–1945) that many of the ideas for this paper were formulated. This article was prepared to acquaint wildlife technicians with aerial photography and to suggest ways of obtaining photographs and of utilizing them more widely and efficiently in the field of wildlife management. The sources of photographs and equipment listed herein are not exhaustive. They are included only as a matter of convenience to the reader and are in no sense to be considered as advertisements for these companies or organizations.

Stegeman (1939) pointed out that three dimensional or stereoscopic pic-

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The writer wishes to express his thanks and appreciation to Dr. G. A. Swanson and Messers E. R. Kalmbach, F. C. Lincoln, W. L. McAtee and R. H. Smith of the Fish and Wildlife Service, Drs. C. A. Dambach, C. F. Walker and Mr. G. A. Petrides of the Ohio State University, Mr. R. N. Bach of the North Dakota Conservation Department, Mr. C. S. Spooner, Chief of the Relief Map Division, Army Map Service and Dr. W. E. Wrather of the U. S. Geological Survey for their helpful suggestions in the preparation of this paper; to Drs. L. E. Yeager and E. R. Kalmbach and Mr. G. P. Spinner of the Fish and Wildlife Service and Mr. W. N. Wandell of the Illinois Natural History Survey, who kindly read the manuscript and helped obtain aerial photographs as illustrative material; to Messers E. M. Elmore and Cecil S. Williams, Fish and Wildlife Service who also helped in securing photographs and Mr. James Dunavent, Columbus, Ohio, artist and former photo officer of the U. S. A.A.F., who gave helpful advice concerning types of aerial photographic equipment recommended for use in the field of wildlife conservation.

tures recorded a greater amount of information with greater accuracy than photos taken through a single lens and viewed singly. He urged wildlife technicians to secure stereoscopic cameras or stereoscopic attachments for their cameras and view the photographs with a stereoscope. He did not emphasize, however, the availability of aerial photographs or their importance in wildlife management work.

There have been relatively few published reports in wildlife literature citing the use of aerial photographs except as maps. In recent years, aerial photographs have been used in pictorial descriptions of study areas, Yeager (1941) and Hochbaum (1944) to cite only two instances; and as a basis for cover mapping as done by Dalke (1937), Crawford (1946), Marshall (1946) and others. Petrides (1944) pointed out the possibility of applying the principles of naval aircraft recognition to wildlife study by the split-second projection of aerial photographs showing deer, for example, as they would appear to observers in making an aerial census. Spinner (1946) suggested an improved segment method of estimating the numbers of birds seen in large flocks by the use of aerial photographs. He compared aerial photographs portraying known numbers of birds in flocks with large flocks of birds in the field.

The Bureau of Marine Fisheries of the California Division of Fish and Game made use of aircraft and aerial photographs in conducting a sea lion census in 1946 (Anonymous 1946). Wilcox (1940), Burwell (1942), Seely (1942), Wieslander and Wilson (1942), Spurr (1945) and others have described uses of aerial photography in forestry.

The use of aircraft in making aerial surveys of big game has been described by Bell (1937), Young (1938), Bennett, English and McCain (1940), Bach (1941 and 1945), Saugstad (1942), Rasmussen and Doman (1943), Olsen (1945), Hunter (1945), Aldous and Krefting (1946), Morse (1946) and Stuart (1947). Miller (1946) described the use of airplanes in censusing upland game in North Dakota under winter conditions. Fisher (1942) reported on the use of airplanes for censusing antelopes in Texas and driving or herding these animals in connection with trapping them.

An exhaustive bibliography on aviation and economic entomology has been prepared by Hawes and Eisenberg (1947). This bibliography includes 1,084 references to the use of aircraft in economic entomology work.

TYPES OF AERIAL PHOTOGRAPHS

The two main types of aerial photographs are the *oblique* and the *vertical.* Vertical photographs are those made when the axis of the camera is kept as nearly at right angles to the earth's surface as possible (Plate 4). Oblique photos are those made with the optical axis of the camera at an angle to the vertical. *High obliques* are made at a high angle to the vertical so as to show the horizon, while those made at a lower angle in which the horizon is not shown are known as *low obliques* (Plate 5). *Composite* aerial photographs are made with cameras having one principal lens and two or more surrounding and oblique lenses. The resulting photographs are rectified or transformed by means of a special projection printing machine so as to permit their assemblage as verticals with the same scale.

A *mosaic* consists of several overlapping vertical photographs joined together. *Uncontrolled mosaics* may be made simply by matching detail in the overlap or along the borders of prints. This type of mosaic gives a good pictorial effect of the ground, but may contain considerable errors in scale and direction. *Controlled mosaics* are obtained when several photographs are oriented by means of points along the line of flight and adjusted on previously selected ground points (Smith 1943). This type of mosaic is more accurate. When several photographs taken from a single airplane flight are joined by matching detail along the borders of each print, the result is a *strip mosaic.* Mosaics are used to provide a continuous view of areas too large to be covered by a single photograph. Continuous or uninterrupted *strip photographs* can now be taken by means of special cameras. *Photomap* is a general term used to denote reproduction of vertical aerial photographs, composites or aerial mosaics. As the term implies, photomaps are used primarily as maps.

Aerial photographs obtained from governmental and private agencies usually have data on their margins which aid in their use. Such information may include arrows indicating north and the direction of flight of the aircraft, locality, altitude of plane, focal length of camera, date and hour of exposure and serial number of the negative.

THE MAKING OF AERIAL PHOTOGRAPHS

The taking of aerial photographs and their development and printing have become specialities with which the user of photographs frequently has no direct connection. For a discussion of aerial cameras and the making of aerial photos, the reader is referred to Smith (1943) and other works cited by him. The Manual of Photogrammetry, 1944, Pittman Publishing Corporation, New York, is an excellent reference on aerial photography and is the official publication of the Society of Photogrammetry. Much information can be obtained also by writing to the manufacturers of aerial photographic equipment and to aerial survey companies.

It suffices to say here that aerial photography should be carefully planned, taking into consideration the time of day, season of the year, correct altitude for obtaining photos of the desired scale, and many other factors. For vertical photography, a plane with an opening in the floor of the cabin or cockpit is needed. Oblique photos can be taken by pointing a hand-held camera over the side of the plane or through a window, either open or closed.

Most vertical photographs are taken in sequence along the line of flight in such a manner that the individual photos overlap in area about 60 per cent. A pilot who takes pictures for mapping purposes usually flies in parallel strips close enough together that there is also a *sidelap* of about 30 per cent on the prints to ensure complete coverage.

PRESENT STATUS OF AERIAL PHOTOGRAPHY IN THE UNITED STATES

Most of the continental area of the United States has now been photographed from the air. A large part of the photography has been accomplished since the middle thirties by the United States Department of Agriculture, the Geological Survey, the Coast and Geodetic Survey, the Tennessee Valley Authority and the Army Air Corps.

Marshall S. Wright (1946) stated that from 1926 to June 30, 1945, the U. S. Department of Agriculture contracted for or executed directly, 2,945,000 square miles of vertical photography at a cost of $9,014,000 or $3.06 per square mile. This photography, for the most part, was of a scale of 1:20,000 and covered nearly all of the agricultural land of the United States. A map showing the extent of aerial photography by the Department of Agriculture as of March 31, 1946, is available from the Office of Plant and Operations, Washington 25, D. C.

W. E. Wrather, Director of the U. S. Geological Survey, stated (*in litt.* May 17, 1946) that about 85 per cent of the land area of the United States is covered by aerial photography of Federal Agencies. Although most of this photography was restricted for public use during the war, it is now being released for purchase and usually can be obtained in the form of contact prints, general enlargements, ratioed enlargements and copy negatives.

SELECTING PHOTOGRAPHS FOR USE IN WILDLIFE MANAGEMENT

With aerial photographs available for most of the United States, it would seem desirable that they be used more frequently and effectively in the field of wildlife management than at present. Choosing the correct type of photography becomes an important consideration in ordering photographs already available or in contracting for additional aerial photography of any given area.

For mapping purposes, vertical photographs are the most desirable type. They show an area somewhat as it would appear on a detailed map of similar scale and provide the most complete picture possible. The area covered by vertical photos is rectangular in shape and the scale is fairly uniform. Vertical photos with a 60 per cent overlap also permit the use of a stereoscope for detailed study.

Oblique photos are effective for illustrative purposes in that they provide a sweeping view in a more familiar perspective. The high oblique covers a larger ground area than any other type of single photo. Unlike vertical photos, however, with scales fairly uniform on any given print, the scale of an oblique decreases in geometric progression from foreground to background. Ground features may appear considerably distorted on obliques. For example, slopes facing toward the camera are enlarged and those facing away from the camera are reduced in area.

The comparative value to wildlife managers of the different types of photos depends on the purposes for which they are to be used. Oblique photos have advantages for pictorial purposes such as illustrating a certain cover type, portraying the landscape features of a study area or showing details of steep slopes. Verticals are best for making measurements and for detailed mapping. Often, the two types can be used together to advantage. A scale of 1:8,000 or less enables the photo interpreter to obtain much more detailed information about cover types and other features than smaller scale photography of 1:20,000 or more.

The Soil Conservation Service has found that for a comprehensive determination of various factors such as slope and erosion classes, soil types and land-use capabilities, photos on a scale of less than four inches to the mile (1:15,840) are too small (Wright *op. cit.*). Wright also reported that a scale of 1:15,840 was suitable for a variety of uses in forest type mapping. The printing paper should be of good weight, fine-grained and with semi-matte or glossy finish so that magnifying stereoscopes can be used in examining the photographs.

Aerial photographs in color, although expensive, are well adapted for showing the extent of serious damage to forests caused by insects, diseases, or fires and for other special illustrative purposes.

HOW AND WHERE TO OBTAIN AERIAL PHOTOGRAPHS

After the proper type of aerial photography has been selected, the next step is to ascertain the agency having the negatives that cover a designated area. This information usually can be obtained at the County, State or Regional Offices of the Department of Agriculture or by writing to the Map Information Office, Geological Survey, Department of the Interior, Washington, D. C.

If possible, the serial numbers of the photos covering the desired area should be obtained before placing an order for photographs. Index maps of Agriculture Department photography from which these numbers can be obtained are usually available at the state and local offices of the Department of Agriculture. Photo index sheets may be obtained also at 60 cents per sheet from the Map Information Office at Washington, D. C.

It should be remembered that if only small scale photographs of a given area are available, enlargements usually can be obtained which will give the desired amount of detail.

Orders for reproductions from the proper negatives should be sent to the agencies holding the negatives. In the case of the U. S. Department of Agriculture, orders should be mailed to the Office of Plant and Operations, U. S. Department of Agriculture, Washington 25, D. C.

Orders for U. S. Geological Survey photography should be sent to The Director, Geological Survey, Department of the Interior, Washington 25, D. C.

According to W. E. Wrather (*in litt.* 1946), aerial photographs from either the Geological Survey or the Department of Agriculture can be purchased at the following prices: "prints, 1–5, 65 cents each; 6–100, 40 cents each; over 100, 35 cents each; county coverage, 30 cents each." These prices are, of course, subject to change.

The Department of Commerce, the War Department and the Navy Department also have some aerial photographic coverage of the United States. Inquiry concerning its availability and cost as well as scale, flying height and other data can be obtained from the respective departments.

If recent photography of the desired type is not available, it may be feasible to make a contract with a commercial firm to take and develop the photographs. For state conservation departments and other agencies requiring considerable aerial photography, it might be practical to purchase some of the outdated but none-the-less usable photographic equipment available as surplus war goods, and to take their own pictures. In many localities, men with considerable wartime experience in aerial photography would welcome an opportunity to do photographic work on a part time or full time basis.

For wildlife agencies contemplating the purchase of surplus equipment, it is suggested that the Fairchild Models K-17-C and K-20 would satisfy most of the requirements. The K-17-C may be operated manually or by a 24-volt power unit in the plane and can be used for both large and small scale vertical photographs. It has a 12 inch focal length and takes 9″×9″ photographs. For all-around use, the following accessories are recommended:

(1) Extra A-5-A magazines
(2) A-8 ring mount for taking verticals
(3) A-2 viewfinder for verticals
(4) B-2 or B-3 intervalometer with cables
(5) Filter set including Wratten K-2, Aero 2, G, 23-A
(6) B-1 Cut film back for Kodachromes

The K-20 is a smaller camera which can be held in the hands and used to good advantage in taking obliques. It has a $6\frac{3}{8}$ inch focal length which enables the operator to take large scale photographs of subjects impossible to get with the larger types of cameras. The Speed Graphic camera with 4″×5″ film pack gave good results in big game aerial census work in Minnesota according to M. A. Morse (*in litt.* May 6, 1946).

Another possibility is that of obtaining aerial photographs from various units and squadrons of the U. S. Army and Navy throughout the country. These squadrons frequently make trial flights for training purposes and for improving their aerial reconnaissance techniques. They willingly cooperate with federal and state agencies, making available excellent quality photographs at little or no cost.

METHODS OF STUDYING AND INTERPRETING AERIAL PHOTOGRAPHS

A great deal can be learned from a detailed study of aerial photographs that escapes the attention of the casual observer. To get the most out of a photograph, it is necessary to have an accurate determination of the scale, have the photograph correctly oriented, have a knowledge of the field in question and exercise sound reasoning.

In examining a photograph, shadows cast by objects on the print should normally fall toward the observer. If

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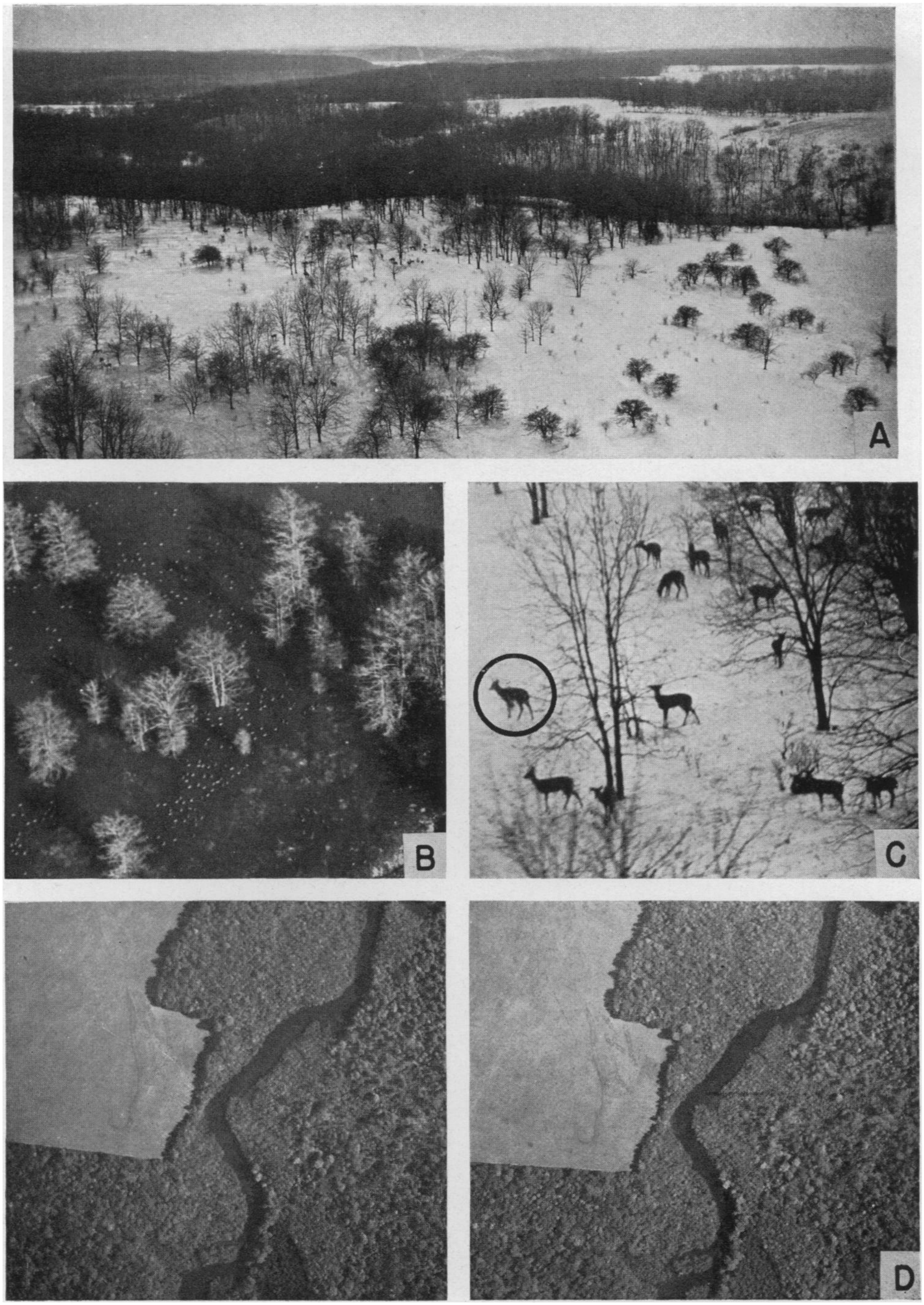
EXPLANATION OF PLATE 4

A. A section of a vertical photograph showing ducks (pintails and widgeons) at Laguna Madre, Texas, January 27, 1947. Viewed by means of a reading glass if used singly or through a stereoscope if used in stereo-pairs such photos are of much value for waterfowl censusing. Photo by Chief Petty Officers J. W. Temple and S. Peters using a K-17 camera in a Navy PBY. Scale, approximately 1:1,000.

B. Section of a vertical photograph showing ducks at Barr Lake, Colorado, January 13, 1947. The use of a stereoscope on such photos will enable the technician to obtain more accurate counts than by viewing single photographs or by attempting aerial counts alone. Photo by courtesy of Army Air Forces, Lowry Field, Colorado. Scale, approximately 1:900.


A


B


A
B
C
D

the photograph is not correctly oriented with respect to the light used for reading it, the relief may seem reversed with valleys appearing as ridges and vice versa.

In reading single prints or mosaics, the photo interpreter relies chiefly upon form, pattern, color tone and shadows in recognizing natural and man-made features. Magnification of from 2 to 4 diameters brings out many details on single photos and often helps one to visualize relief. Examination of paired photos which overlap in area can be made with the aid of a stereoscope. It is only through the use of a stereoscope that the full potentialities of aerial photographs can be realized.

Stereoscopes are of two main types, the refraction, or lens type, and the reflection, or mirror type. The refraction is the more simple and compact, consisting of 2 matched lenses separated by a distance corresponding to that between the eyes and mounted on a suitable support. The lenses usually have a magnification of from 1.25 to 4 diameters. A magnification of about 2.5 is good for average work.

The reflection type of stereoscope consists of four mirrors set at angles of 45° to the plane of the photos. This type of stereoscope costs more and is less compact than the simple refraction type. The refraction type, due to the magnification of the lenses, also has the advantage of providing a more detailed view with a heightened relief effect. All things considered, it is probably the most useful type for wildlife managers. At the time of writing, simple refraction types of stereoscopes could be obtained from optical companies at a cost af about $10.00 each.

For detailed instructions in using a stereoscope, it is suggested that the readers who have had no experience in photo interpretation refer to texts such as those cited previously or contact someone who is familiar with the procedure, perhaps in Soil Conservation Service or Production and Marketing

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EXPLANATION OF PLATE 5

A. High oblique of the Rock River, Illinois deer habitat, Ogle County, February 10, 1947. Note the deer in the foreground and the horizon in the background. Photo, courtesy Willet N. Wandell, Illinois Natural History Survey. Camera used: Fairchild K-20.

B. Low oblique showing waterfowl on Horseshoe Lake, Alexander County, Illinois, January, 1947. Obliques taken at low altitudes complemented by large scale vertical photos make possible fairly accurate counts of ducks even in sparsely wooded areas such as this. Photo, courtesy Cecil S. Williams, Fish and Wildlife Service. A K-20 aerial camera with 4″×5″ negatives was used for making this photo, only a section of which is reproduced here.

C. Section of low oblique showing ease with which deer can be counted under these conditions of scattered deciduous trees and snowy background. Photo, courtesy Willet N. Wandell, Illinois Natural History Survey. As indicated by Willet N. Wandell the encircled deer at the left of this enlargement is evidently a buck that retained his antlers up until the time of photography, February, 1947.

D. A stereo pair of photographs taken at an altitude of 5,000 feet. Note the livestock grazing in the pasture and the stream winding through the forested area. Bombay Hook Refuge. 5*D* to 6*B*, courtesy Colonel Donald B. Diehl and Master Sergeant Robert Livingston, 4146 Base Unit, AMC; USAAF.

Agency offices. Essentially, all that is required, however, is to place two photos in correct overlapping relation to one another, set the stereoscope directly over two complementary image points on the photo approximately 2.5 inches apart and stare at these points (a cross-roads for example) until stereoscopic fusion is obtained. Only a very little practice will be necessary before most people with normal vision can readily get true depth perception. Wildlife managers and others who use aerial photographs will find their efforts well justified in obtaining a stereoscope and in learning to use it.

In beginning a study of aerial photographs, it is desirable to know the scale, the location, the date, the correct compass orientation, the focal length of the camera used and the time of day when the exposure was made. As indicated earlier, some of this information is usually on the margin of the photographs. If not given, the scale may be calculated (1) from the altitude at which exposure was made and the focal length of the camera, (2) by determining the ratio of distances between selected points on a map of known scale and the same points on the photo, and (3) by ground measurements of distances between points that can be identified on the photo. Scale is usually given in terms of a simple fraction as 1/8,000. It expresses the relation of photo distance to ground distance in like units of measurement. The scale may also be converted into other terms such as miles or feet per inch. To calculate the scale (representative fraction) by focal length and altitude, the following formula may be used:

$$RF = \frac{\text{Focal length in feet}}{\text{Height of airplane in feet}}.$$

Thus, if an exposure is made at an altitude of 20,000 feet with a camera having a focal length of 12″ (1 foot), the scale of the resulting photograph would be 1:20,000. If the camera had a focal length of 6″ (.5 foot), the scale would be 1:40,000 or if the focal length were 24″ (2 feet), the scale would be 1:10,000.

If the altitude given is the elevation above sea level, and if the average ground level is much above sea level, allowance must be made by reducing the altitude used in the formula the necessary amount, *i.e.*, the elevation of the ground above sea level.

In computing the scale by comparison of two points on a photograph with points on a map of known scale or by comparison with ground distance, it is well to select two points near opposite corners of the photo so that a line joining the points will pass close to the center of the picture. Then, assuming that the distance between the two points is 3 inches on a map of 1:50,000 and the distance between these points on a photograph is 6 inches, it is apparent that the scale of the photograph is just half that of the map or 1:25,000.

Orientation of the photos may be accomplished by comparing them with maps or by orienting them with some recognizable feature on the ground such as a road. A third method is by the use of shadows which, in most of the Northern Hemisphere, fall towards the northwest, north or northeast in the morning, at noon or in the afternoon respectively.

The identification of features on photographs requires a certain amount of practice and it is well if the interpreter can actually compare the photographs with features on the ground. By so doing, he can soon learn to recognize natural and man-made features represented on the photographs. He can also learn the limitations of any type and scale of photography for a given purpose.

The shape of an object, and the shadow, it casts, are very important aids in identification. Lombardy poplars, for example, can be identified by these means and differentiated from more branching and sprawling types of trees.

The apparent size of objects or their relation to associated features is also important in photo interpretation. Objects too small to be readily identified on photos may be distinguished by studying their relation to surrounding known features.

Pattern is often helpful. Orchards or plantations of trees, for example, can be distinguished from natural forest land by the regular spacing of trees. Various types of land-use and field patterns are also easily recognized. Streams may be identified according to the meandering or dendritic patterns and the vegetation commonly growing along them (Plates 5 and 6).

The third dimension or stereoscopic relief revealed under the stereoscope is of great importance in most phases of photo interpretation. The use of a magnifying stereoscope brings out many details of topography, drainage, vegetation types and other features otherwise impossible to recognize.

Smith (*op. cit.*) designates the texture of photographs by various descriptive terms as coarse or fine, smooth or rough, even or uneven, granular, matted, wooly etc. Grassland shows an even to mottled texture, bare sand and quiet water have a smooth, even texture, forested land is usually characterized by a rough texture.

The color tone of aerial photographs varies considerably with the type of film and filter used, the nature of the topography or features photographed, the angle at which the photos were taken, the manner in which light is reflected from the objects photographed and other factors. The color tone of plowed fields is generally grayish and may vary from almost white in dry, sandy areas to dark gray in areas of muck. Vegetated areas of forest or grassland usually show a dark color tone.

The stereo pairs shown in Plates 5 and 6 indicate the manner in which size, relation to associated features, pattern, texture, stereoscopic relief and color tone are helpful in the recognition of ground features represented on aerial photographs.

The methods for determining the heights of objects represented on aerial photographs are described by Smith (*op cit.* pp. 10 and 89). Seely (1942) and Spurr and Brown (1946b) have described how to determine tree heights by various methods. The latter investigators stated that forest stands could be classified accurately into 10-foot height classes at a photographic scale of 1:16,000 and into 5-foot classes at a scale of 1:12,000. The parallax ladder as used by the Photographic Intelligence Center, Navy Yard, Washington 25, D. C., is said to be a simple inexpensive device for the determination of elevations from aerial photographs even without the use of a stereoscope.

Several factors affect the accuracy with which heights may be obtained—slope of the ground, tilt of the airplane, density of foliage in the case of trees, and the angle of photography. To obtain heights by the use of shadows, it is necessary to know the time and date of exposure, the latitude of the object photographed and the length of the shadow. Height values based on the length of shadows are accurate only when the shadow is cast on flat ground and the base of the object which casts the shadow is visible beneath the point or edge where the shadow begins.

With some practice, it is possible to judge relative heights fairly well by simply noting the length of shadows cast and comparing them with known features of the landscape.

SUGGESTED USES OF AERIAL PHOTOGRAPHS IN WILDLIFE MANAGEMENT

The following uses for aerial photographs in the field of wildlife management are suggested with the hope that they may be tested and that they may result in the further application of aerial photography in wildlife research and management.

MAPS

Two important and widespread uses of aerial photographs are as maps and as aids in map making. They may be used as guide maps because they show roads, tracks, ridges and streams in their proper relation and are of much value in the original inspection or survey of a wildlife management area.

They may also be used as base maps for recording various kinds of data including land-use, soil types, vegetation types, refuge areas, property lines and other features. Aerial photographs used singly or in mosaics may thus serve as a base for making contour maps, cover maps, soil maps and land-use maps. They are useful for determining the size of areas and planning land-use readjustments.

Photographs to be used as guide or base maps preferably should be mounted on some sort of base cloth such as Chartex to prevent tearing and cracking. Chartex is manufactured by Seal, Incorporated, Shelton, Connecticut. It is obtainable in cut or roll form and is easily applied.

Cover maps can be made most accurately from large scale, vertical photographs of good quality. The photo interpreter or technician making the cover maps should be familiar with the area and determine the accuracy of his interpretation with frequent ground studies of the vegetation. Wieslander and Wilson (1942) described a system used in classifying forest and other vegetation types in the Forest Survey of California and Western Nevada.

Spurr and Brown (1946a) in discussing the specifications for aerial photographs used in forest management pointed out that the best resolution of detail was obtained with Kodak Type B infra-red film using a minus blue No. 12 filter. With such film they found that red pine, red spruce and Scotch pine appear very dark on photographs; white pine, white spruce and Norway spruce have a gray tone; hemlock European larch and tamarack have a light gray tone and hardwoods such as red maple, sugar maple, red oak, white oak and paper birch appear on the photographs in a very light tone. These same observers indicated that photographs of a 1:15,840 (four inches to the mile) scale were almost universally applicable for forestry work, but recommended a 1:9,600 scale for intensive management and for volume estimating.

The making of contour maps from aerial photographs is treated in considerable detail by Smith (*op. cit.* pp. 192–216). A planimetric system of mapping, used by the Soil Conservation Service, is described by Cude (1940).

Complex instruments may now be obtained from Bausch and Lomb, The Aero Service Corporation, the Fairchild Camera and Instrument Corporation, the Abrams Instrument Corporation and others which are excellent for the transferring of information from an aerial photograph to a mapping base, and at the same time making change in scale and correction for tilt. These instruments are fairly expensive and require some skill in operating them, but would be desirable for large scale mapping projects.

EVALUATION AND DETERMINATION OF GAME RANGE

Aerial surveys of game range are the most practical approach to the study and management of wildlife tracts in wilderness areas and extensive marshlands inaccessible to automobiles and other means of transportation. Even in more accessible areas, aerial surveys may be more economical than the slower and more tedious ground surveys. Much can be learned by direct observation from low flying planes, but aerial photographs, taken of the wildlife areas flown over, add much to the value and utility of such aerial surveys. Detailed stereoscopic study of aerial photographs should enable a game technician to learn much about habitat conditions at the time of the survey and the photographs provide a permanent record for comparisons and future uses.

For example, aerial photographs used in conjunction with ground studies would enable a game technician to outline with considerable facility and accuracy the potential deer range in a given locality (Plate 7). Wooded or brushy areas are readily discernible on mosaics made of small scale photographs representing relatively large areas.

In extensive nesting areas of waterfowl, seasonal variations in the flooded and unflooded sections could be mapped with a minimum of time and effort using aerial photographs. If the success of nesting on representative sample areas were determined by ground studies, estimates could then be made for the waterfowl produced on much larger areas. Relatively small scale photographs each covering a large expanse of marsh would be suitable for such mapping and cost much less than large scale photography. If it became desirable to study some particular part of the marsh area in detail, enlargements could be made from the negatives covering that part.

In conducting studies of ground nesting birds such as the pheasant, it has been learned that in certain years many nests are destroyed by flooding. The extent of such flooding could be readily shown by photographs taken at the peak of a flood. The losses in pheasant production due to nest destruction would obviously have to be determined by intensive nesting studies made on the ground on sample areas. In flat regions, as in much of the pheasant belt of northwestern Ohio, a difference in elevation of only a few inches may mean the difference between flooding or not flooding after periods of heavy precipitation. Such slight differences in elevation are not readily apparent to a man on the ground, but should be considered in a pheasant management program which has as one of its chief aims the establishment of undisturbed nesting cover strips. By referring to photographs or mosaics of an area in flooded condition, the establishment of nesting cover, in localities likely to be flooded, could be avoided.

As an Aid in Censusing Animals

Although aerial surveys of big game were made as early as 1931 in Utah by Orange Olsen (*op. cit.*) and are now being employed in many states, there has been very little use of aerial photography in conjunction with the direct counts of game animals made by the aerial observers.

In Minnesota, some aerial photographs were taken during their aerial survey of big game, but they were not used to check the accuracy of the game tallied from the air (Morse *in litt.*, June 6, 1946). It is the considered opinion of the writer that the use of aerial photographs as a check would be a worthwhile addition to the aerial census method and Morse indicated that he expected to use this approach in the future. Willet Wandell (*in litt.*, April 24, 1947) reported on the aerial census of deer on the Rock River, Illinois, area and stated that aerial photos of one herd revealed 109 animals rather than the 105 observed from the air. Photographs of other deer herds censused might have shown greater differences obtained by the two methods. Donald D. McLean (*in litt.*, April 10, 1947) stated that a K-20 aerial camera had been used to photograph antelopes and Rocky Mountain mule deer in California as a part of their recent aerial survey of big game.

Morse (*op. cit.*) pointed out that for counting moose and deer, the optimum altitude for flying was about 500 feet. At this height, two observers could view a strip $\frac{1}{8}$ to $\frac{3}{16}$ mile wide for big game. A light plane seating three people and flying at a speed of 60 to 80 miles per hour was considered suitable for aerial surveys of this type. Morse also reported that in Minnesota, the cost of their aerial censuses to date had been \$1.09 per square mile in comparison to the \$220.00 per square mile cost of census by the deer drive. A deer drive required approximately 160 man days of labor for the census of one square mile. On five aerial censuses made in Minnesota, only 62 man days of labor were expended to census 746 square miles. These differences represented tremendous savings to the state.

Large scale photographs taken along the flight line of the aircraft and examined carefully under a stereoscope would make possible more accurate counts of big game than visual observations alone. The photographs would also form a permanent record of the condition of the range at the time of photography and show what part of the range was occupied.

Continuous strip photography would appear to offer possibilities for aerial census work. As reported by Kistler (1946) the Sonne stereoscopic strip camera was an important advance made in World War II. This camera makes possible low altitude, large scale (up to 1:300) photography at high plane speeds. The film is moved continuously past a slit in the focal plane of the camera and is synchronized to the movement of the ground image as the airplane passes over the terrain. As the airplane moves in flight, the film continuously records the terrain passing below on an uninterrupted strip photograph. Stereoscopic photos are obtained by partitioning the lens cone and using two lenses. The strip photographs can be viewed stereoscopically on the continuous roll by means of a special mirror type of stereoscopic viewer. The writer has seen this type of photography demonstrated with splendid results, but knows very little about the type of equipment required, the costs and other details. These details could be obtained from the Chicago Aerial Survey Company and other commercial companies.

The type and density of cover, weather conditions, topography and season of the year should all be considered before attempting an aerial census of big game. Favorable conditions for the aerial censusing of deer include a range of deciduous forest species from which the leaves have fallen, a snowy background, good flying weather and a topography not too rough in character. The banding and movements of big game animals should also be considered. For example, in North Dakota Bach (*op. cit.*) and Stuart (*op. cit.*) found that a census in late August and early September provided a more representative picture of the resident antelope population than an early summer census, before any fall banding had occurred, or a winter census, when most of the animals had migrated out of the state. Usually, antelopes and buffalos would be visible on photographs even without a snowy background. Rasmussen and Doman (*op. cit.*) found that mule deer in Utah and other western states were difficult to census by airplanes due to the rough mountain ranges and the fact that the deer's main winter range in that region was of the pinon-juniper type. Deer could not be seen in aerial photos of dense coniferous cover even in the winter. They would appear, however, on photos of valleys or slopes with deciduous cover even though they could not be seen readily by observers in a plane traveling 90 to 100 miles per hour. Due to the location and type of habitat in which caribou are found, the aerial census of these animals would appear to be a feasible method of determining their numbers.

Muskrat houses in marsh areas are recognizable on aerial photographs and can be counted much more readily and completely than by attempting to record them from a boat or from the borders of a large marsh (Plate 6, *A*). If the numbers of muskrats represented per house could be satisfactorily determined by ground studies preceding an aerial survey, the number of houses multiplied by an accurate conversion factor would indicate the number of muskrats on a given area.

The number of muskrat houses appearing per unit of area on a photograph taken in the fall might also be used as an aid in determining the number of muskrats that could be removed safely during the trapping season. As the number of muskrats represented by a muskrat house varies from year to year and according to the season of the year, any estimates on muskrat populations determined by a count of the houses must be based on careful ground studies preceding the aerial photography. Vertical photographs of a scale of 1:4,000 up to 1:10,000 are suitable for muskrat house counts.

David B. Vesall summarized his experiences in the aerial census of muskrats in Minnesota at the Midwest Wildlife Conference held at Columbia, Missouri, December 5–7, 1946. He stated that in three days of flying, totalling fifteen hours and twenty minutes flight time, a four-man crew censused a strip of muskrat marsh 1,487 miles long by one and one-half miles wide at a total cost of $335. Some photographs taken concurrently with the aerial survey would have provided permanent records of considerable value in a research or management program and would have served as a check on the accuracy of the counts made by the observers as they flew over the marsh.

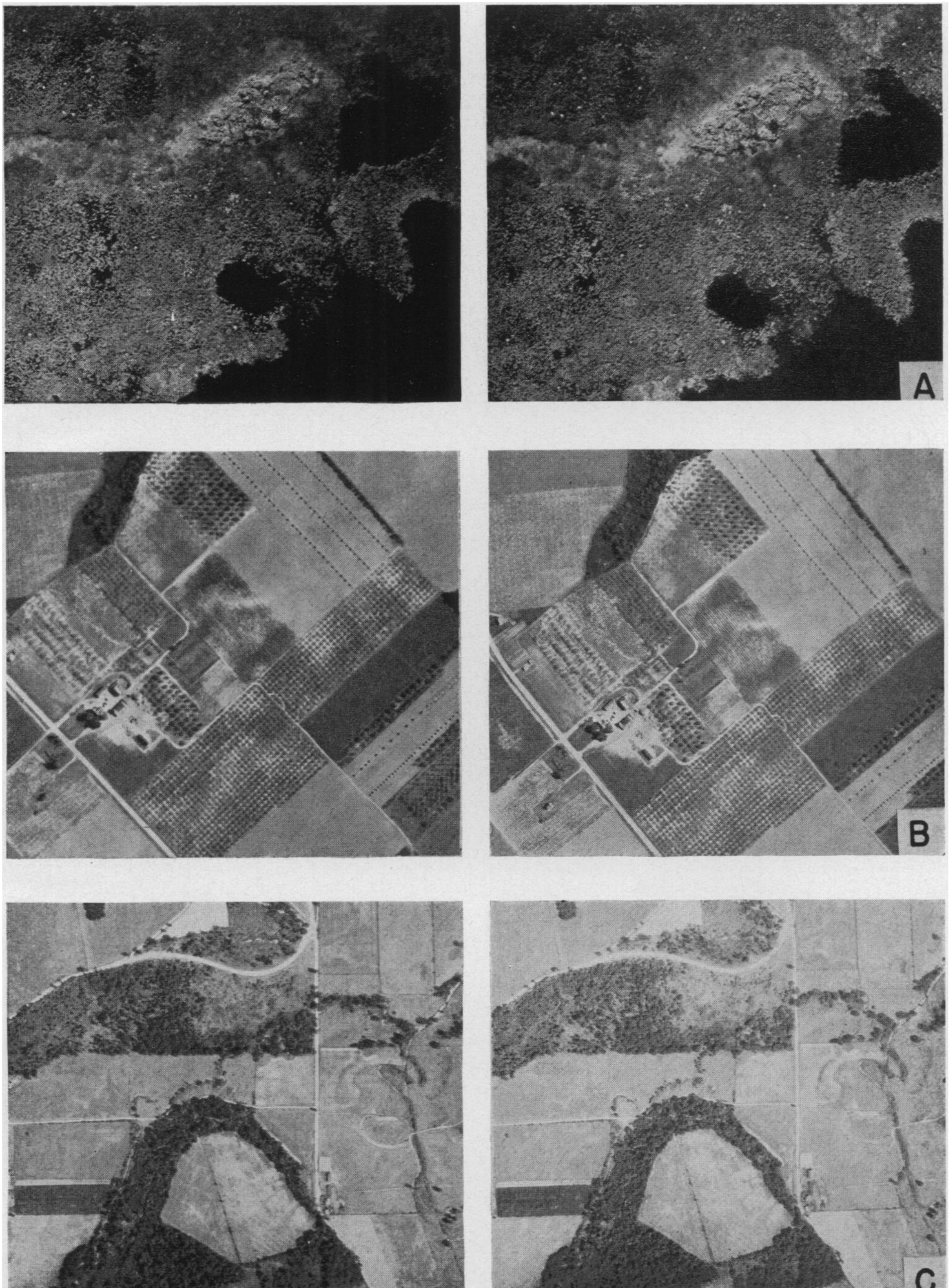
The U. S. Fish and Wildlife Service and the Illinois Natural History Survey have employed airplanes in their studies of waterfowl for several years. Aircraft are now being used as a means of estimating numbers of waterfowl especially during the winter. Large scale photographs taken during the aerial surveys of waterfowl would serve as a valuable check on the counts made by observers in a plane. The excellent aerial photographs exhibited by Dr. E. R. Kalmbach and Mr. E. M. Elmore at the North American Wildlife Conference in 1947 show that accurate counts can be made of enormous rafts or flocks of ducks. On small scale photographs in which individual ducks cannot be counted, the area represented on the photographs as well as the percentage of the total area occupied by rafts of waterfowl could be calculated easily and multiplied by a conversion factor to indicate the total number of waterfowl present. The conversion factor *i.e.*, the number of ducks actually present on selected areas, could be obtained (1) by ground counts, (2) by enlarging some of the small scale photographs so that individual ducks can be counted or (3) by direct observation from a low-flying plane. Mississippi Flyway Biologist, Robert H. Smith (*in litt.*, Sep-

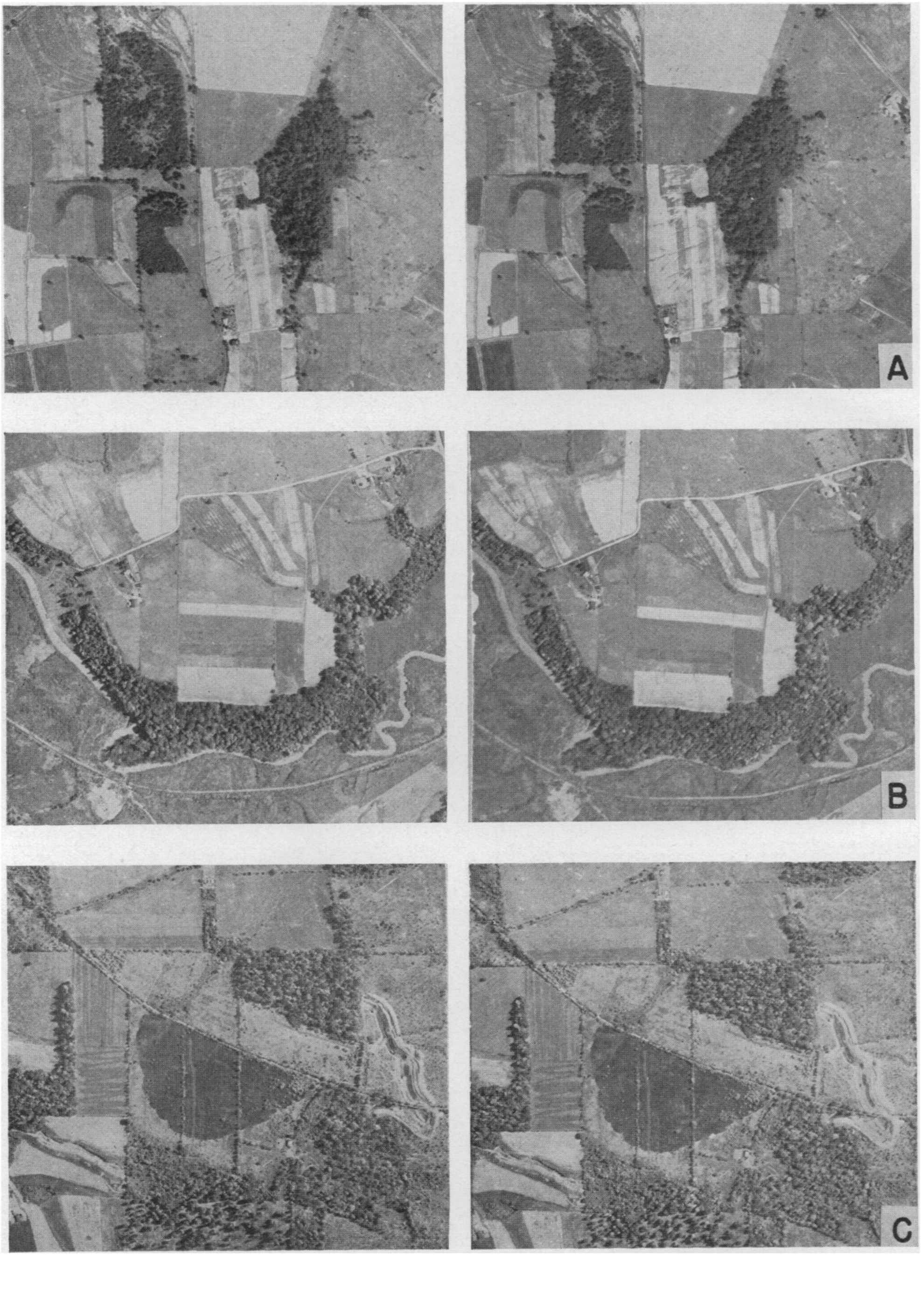
EXPLANATION OF PLATE 6

A. Sections of vertical photographs taken October 9, 1945, showing muskrat houses on the Blackwater Refuge, Delaware. The water area appears dark and the muskrat houses light in contrast to the marsh vegetation. At a scale of 1:5,000 a 9×9-inch print represents approximately 322 acres of marsh land and furnishes an accurate, cheap means of determining the number of muskrat houses on large, relatively inaccessible marsh lands.

B. Note the regularity of the orchards, plantations and truck gardens as contrasted to the native wooded tract on the Bombay Hook Refuge, Smyrna, Delaware. Note also the shocked corn and other agricultural crops; the woody as contrasted to the clean field borders and the mottled dark and white effect of the various soil types indicating differences in natural drainage.

C. A steep-sloped valley in eastern Ohio. Note the hilly topography shown by these and the following USAAF photos taken in Tuscarawas County, Ohio, September and October, 1942, at a scale of approximately 1:18,000. Much of the land here is devoted to pasture.


A
B
C


A
B
C

tember 27, 1946), reported that "waterfowl are easily identified from aircraft moving at ground speeds up to 130 miles per hour and at elevations not to exceed 200 feet." Smith pointed out further that often after a raft of ducks has been photographed, it would be much cheaper to make a low flight over the raft to estimate the percentage composition of species than to make a special trip by ground or water for this purpose because the rafts are sometimes inaccessible.

The chief advantages of flying at relatively high elevations in photographing rafts of ducks are (1) the small scale photographs cover larger areas and are relatively cheap and (2) the ducks are not frightened by the airplane.

Observations from the air in conjunction with aerial photographs would appear to be the most practical method for censusing large rafts of ducks on open water in relatively inaccessible areas. It would be impractical, of course, for economic reasons, to photograph the entire range over which wintering waterfowl are dispersed. Stereoscopic examinations of photographs should be made in counting ducks which might be partially hidden by trees or other vegetation along river banks or in swamps (Plates 4, *A-B*, and 5, *B*).

Mr. George P. Spinner (unpublished ms, 1946) was able to count individually all of the geese in an aerial photograph of the Greater Snow Geese. These geese, which were resting in the Bombay Hook National Refuge, were chased out over the bay to provide a dark background for the photograph; being white, the birds showed up exceptionally well.

Miller (*op. cit.*) reported on the use of the airplane in censusing upland game birds in North Dakota. He found that, due to heavy snows, pheasants and other upland game could be counted easily from a plane flying at an altitude of 100 to 300 feet whether they were in patches of sweet clover, weeds or other cover. Large scale photographs might be of some value in counting particularly large groups of such game birds in winter concentration areas, but would be impracticable for many areas with sparse populations.

Such animals as seals grouped together on ice appear quite plainly in aerial photographs as illustrated by Bartlett (1929: 13) in an article en-

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EXPLANATION OF PLATE 7

A. Severe gully erosion appears on the slope shown near the center of these aerial photographs. Contrast the land use here with that illustrated in photo 6B. Note the extensive pasture to the right which is reverting to forest and providing more deer territory in eastern Ohio.

B. Note the wooded slope which, here, is about 40 feet in height, the strip-cropping now being practiced to combat soil erosion losses, the gentle curve of the abandoned railway which follows the valley and the sharp curves in the secondary highway on the upland. The lighter toned trees are assuming their autumn colors.

C. More deer and grouse country in the making here. The dark area near the center of the photographs results from a grass fire; the dark streaks in the field to the left indicate that manure was spread here for pasture improvement. To the right and lower left are strip-mined areas with considerable wildlife management potentialities.

titled "The Sealing Saga of Newfoundland." The possibility of obtaining seal censuses by the aerial survey method thus seems obvious. As indicated earlier (Anonymous, *op. cit.*) the Bureau of Marine Fisheries used aircraft and aerial photographs to aid them in the 1946 sea lion census in California. Observers found that they could make counts and estimates of sea lions from airplanes or blimps and that aerial photographs were very useful as a check of such counts. The aerial survey method had a great advantage over counts made from boats in that flights by air permitted coverage of all the state waters in two or three days. Thus complete counts could be made before the sea lions had time to move from rookery to rookery, thereby introducing an error in a survey of similar coverage from boats which would have required two or more weeks to complete.

As an Aid in Locating Game Refuge Sites

Aerial photographs can be of considerable use in selecting potential sites for waterfowl and upland game refuges. Pheasant refuges in Ohio for example, have been found to be most successful when located according to a more or less general pattern with a refuge near the center and others near each of the four corners of a county. By examining aerial photos which already are available, it is possible to select certain areas in strategic localities as potential refuge sites. The location of these potential sites can then be transposed to a county highway map and visited by driving to them directly, thus saving considerable time and mileage. In northwestern Ohio, the most suitable winter cover for pheasant refuges consists of brushy thickets which can be recognized as such on the 1:8,000 scale photographs available. The type of land-use which is of major importance in selecting pheasant refuges can also be determined from aerial photographs.

Some of the potential refuge areas selected from aerial photos would undoubtedly prove to be lacking certain desirable features when examined more closely on the ground, but most of the physical features such as topography, land-use and cover could be determined by using aerial photographs.

In like manner, some of the localities spotted in remote areas by aerial observers as being used for natural resting sites by migrating waterfowl could be photographed, the aerial photographs later serving as an aid in selecting and establishing waterfowl refuges. Since the photographs would indicate the extent to which a given area was used and the parts of the area most occupied by waterfowl, they would be helpful not only in determining good refuge sites, but also in determining appropriate boundaries for these refuges.

As an Aid in Law Enforcement

Various types of aircraft have been used in recent years as an aid in law enforcement work. In some situations, aerial photographs could be used as evidence of game law violations. For example, commercial fisherman may be allowed to fish only in certain parts of a large lake, the illegal or restricted waters being marked by means of buoys. Since these markers or buoys might not be visible from shore and since fishermen might readily move their boats from restricted to legal fishing areas at the approach of a patrol boat, it would be difficult to enforce the regulations prohibiting fishing beyond a certain line. Now if a fishing boat were seen in the restricted waters by observers in an airplane and if the boat were photographed from the air in such a way that its location could be accurately plotted in relation to the legal fishing area, the photograph could be used as indisputable evidence in court.

As an Aid in Mapping and Studying Areas Damaged by Fire, Floods, Insects or Disease

Aerial photographs show very clearly the freshly burned areas in grasslands and wooded areas (Plate 7, *C*). Determining the extent of grassland burns, which appear dark on photographs, might be of considerable value in estimating losses to game as a result of fire. The blackened stubs of trees found in old burned-over forest areas are easily recognized on photographs as are the dead leaves of trees in freshly burned forests. Burned areas likely to provide an abundance of sprout and shrubby growth valuable to deer and other forms of wildlife can be easily mapped from aerial photographs.

Trees which have been damaged by insects or disease so that the leaves have become brown appear as black on infra red photographs, white on panchromatic photographs and in natural color on color photographs (Spurr and Brown, *op. cit.*). Such photographs are of considerable value in surveying damage caused by insects and disease.

As stated earlier, flooded areas can be mapped with considerable accuracy by using aerial photographs. Such photographs may be used to indicate flood damage caused by wildlife as well as damage to wildlife caused by floods. In the level, swampy, forested land of north central Minnesota, Hoene (1946) reported that drainage ditches were plugged by beavers and that the consequent damage to forests by flooding was appalling. According to Hoene, a Minnesota processor of table-size Christmas trees had recently taken aerial photographs and colored motion pictures of the flooded areas in order to show authorities how serious the matter had become. The aerial photograph used to illustrate Hoene's article showed very clearly the flooded, as contrasted with the non-flooded areas of coniferous forests.

As an Aid in Determining Hunting Pressure

On certain areas aerial photos could be used to good advantage in determining the number of hunters in the field at a given time. Large scale, continuous strip photos would be excellent for this purpose. Willet Wandell (*op. cit.*) indicated that two aerial flights had been made over northeastern Illinois for the purpose of determining hunting pressure and that air counts had been made to check the results obtained by ground counts. He indicated further that, although aerial photography equipment was lacking at the time of the survey, aerial photographs would have been very helpful in checking the accuracy of the aerial counts.

Other Suggested Uses

Among the other ways in which aerial photographs might be used in the wildlife conservation field are: (1) in locating, mapping and planning potential dam sites; (2) in preparing soil erosion maps and spotting land-use and wildlife problem areas; (3) in determining changes in vegetative cover and land-use over a period of years; (4) in planning the locations of roads, trails, fire lanes, fire towers and other developmental features of newly acquired areas; (5) in making special studies of rare or vanishing species such as the whooping crane in which complete and permanent records of the habitat types utilized are desirable; (6) in conducting lake surveys including the mapping of emergent and floating aquatic flora and possibly the contour mapping of lake bottoms; (7) in accurately plotting tax delinquent lands in connection with the acquisition of land for game refuge and management areas and (8) in recording pictorially the features of breeding grounds, newly discovered in remote areas, resulting from the increased use of the airplane as a means of travel by biologists.

EXPLANATION OF ILLUSTRATIONS

The illustrations included with this paper demonstrate various types of aerial photography and indicate some of the uses that can be made of aerial photographs in the conservation field. 5D to 7C are verticals arranged in such a manner that they can be viewed through a stereoscope. Readers who have never used a stereoscope are urged to try one on these photos and note the added details which can be learned from a stereoscopic examination. It should be pointed out that original prints of good quality, properly arranged to meet the varying requirements of individuals will give more satisfactory results than these reproductions.

SUMMARY

The primary objectives of this article are to acquaint wildlife technicians with aerial photography and to suggest ways of obtaining aerial photographs and of utilizing them more widely and efficiently in the field of wildlife management. The literature dealing with the use of aircraft and aerial photography in the wildlife field is reviewed; types of aerial photographs are described; the status of aerial photography in the United States is indicated; criteria for selecting photographs for use in wildlife conservation work are discussed; means and methods of obtaining and interpreting aerial photographs are considered. Various types of aerial photographs including stereo pairs are included as illustrative material for study purposes.

Several uses for aerial photographs in the wildlife management field are suggested with the hope that they may be tested and that they may result in the further application of aerial photography in wildlife research and management. These suggestions include the use of aerial photographs as maps; as aids in evaluating and determining the extent of game range; in censusing such animals as big game species, muskrats, seals and waterfowl; in locating refuge sites; in law enforcement; in determining hunting pressure; in studying areas damaged by fire, floods, insects or disease; in locating, mapping and planning potential dam sites; in preparing soil erosion maps and spotting land-use and wildlife problem areas; in determining changes in vegetative cover and land-use over a period of years; in planning the locations of roads, trails, fire lanes, fire towers and other developmental features of newly acquired areas; in