Wildlife Forensics: Past, Present and Future

Michael Stockdale, *Tennessee Wildlife Resource Agency, P.O. Box 95, Big Sandy, TN 38221*

Abstract: The enforcement of wildlife laws becomes more complex and complicated each day and requires the wildlife officer to use every available tool to perform his job. Wildlife forensic techniques provide scientific methods to supplement the wildlife officer's work in the field. Wildlife forensic techniques provide methods necessary to answer law enforcement problems which remained unanswered in the past but have been answered today, and to solve tomorrow's problems with answers which do not exist today. Wildlife forensics is not a panacea for the wildlife officer, however, it is another tool in his arsenal against the poacher. The science of wildlife forensics is similar to air travel. Yesterday's wildlife officer flew a propeller driven plane. Today's wildlife officer has moved into the jet age. Tomorrow's wildlife officer will enter the space age.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 45:504–514

A drop of blood, a few hairs, a small piece of meat in the back of a truck: what does it mean to a wildlife officer? In the past, or the early days of game and fish law enforcement, probably only that an animal had been in the truck. In season or out of season? Male or female? Was it killed before or after legal hunting hours or during legal hunting hours? In the past the wildlife officer did not know or have the capabilities to determine these answers.

Today's wildlife officer can have the hair identified to species and sometimes even determine the sex of the animal from the hair. Frequently the hair will indicate the time of the year (i.e., summer versus winter hair) that the animal was taken or possessed. The blood and meat can be used to identify the species from which it originated.

Tomorrow's wildlife officer will be able to determine the species and sex of the animal from either the hair, blood, or meat sample and if a carcass is available match it to the carcass from which it originated.

The science of wildlife forensics is similar to air travel. Yesterday's wildlife officer flew a propeller driven plane. Today's wildlife officer has moved into the jet age. Tomorrow's wildlife officer will enter the space age.

The Past

Although the origin of modern day wildlife forensics is somewhat clouded and obscured, we do have ample records showing F.P. Gay (1908) used the precipitin test in 1908 to differentiate the difference in samples of veal and venison. Gay's work was followed with what could probably be considered the greatest breakthrough in wildlife law enforcement, a case in California where, for the first time in the United States, a person was convicted with evidence based wholly upon the precipitin test and its ability to differentiate venison from beef, mutton, and bear meat (Clark 1914, Oates et al. 1974).

Following the California case, additional work using the precipitin test was done by Fenstermacher and Pomeroy (1938) to identify blood stains suspected to be beaver. Brohn and Korschgen (1950) also used this method for differentiating deer serum and meat extracts from deer, goat, sheep, cow, and pig (Oates et al. 1974).

Although the precipitin test is still used in many states today, it is not considered genera specific. Therefore, more specific methods have been developed to identify blood and tissue samples to both genus and species.

In 1948 Ouchterlony developed the agar double immunodiffusion technique. Since 1948 thousands of published papers mention agar double immunodiffusion. This method of identification of blood and tissue samples has become so common today that the details are no longer given and it is simply referred to in passing as the "Ouchterlony method" (Ouchterlony 1948, 1968; Oates et al. 1974).

A method even more specific than Ouchterlony's agar double immunodiffusion was developed in 1953 by Grabar and Williams. Grabar and Williams (1953) combined electrophoresis with Ouchterlony's method which resulted in the development of immunoelectrophoresis and allowed the separation of closely related species, such as white-tailed deer (*Odocoileus virginianus*) and mule deer (*O. hemionus*).

The identification of animal hair as originating from a specific genus or species of animal can be accomplished with a minimal amount of equipment and a well-trained specialist. Despite numerous attempts, no reliable, short-cut methods exist for identifying animal fibers. Wildman (1961) summed it up best when he stated, "The only satisfactory procedure is to use the method of microscopy with a sound knowledge of fiber morphology and careful interpretations of the observations made." With the use of hair keys (Mayer 1949, 1952; Wildman 1954; Adorjan and Kolenosky 1969; Brunner and Coman 1974; Moore et al. 1974) a trained specialist should be able to identify all animal hairs to genus and approximately 70%–75% of all hairs to species. The identification of hair from big game and small game species which are hunted can usually be identified to species level.

Wildlife forensics for conservation law enforcement, from the early 1900s through the 1960s, made some advancements but not with the progress or speed that wildlife officers would like to have seen. During this 760-year period wildlife forensics moved from being propeller driven to the beginning of its Jet Age.

The Present

The present state of wildlife law enforcement forensics is greatly advanced today as compared to yesterday's methods. Wildlife forensic techniques which were once only a dream are now reality in many cases. Much of today's current success in wildlife forensic problem solving can be traced to the 1977 Forensic Science Symposium (FSS) held in Calgary, Alberta, Canada. It was at this meeting that wildlife forensic scientists, criminal forensic scientists, wildlife biologists, law enforcement personnel, and administrators met to discuss the current state of wildlife forensics for law enforcement. Discussions were held regarding what different provinces, state, or federal wildlife agencies, universities, or forensic laboratories could currently do, and what the most pressing problems were for wildlife forensic researchers.

The Alberta FSS (1977) identified the following problem areas which either needed research or more research: 1) the ability to consistently distinguish blood and meat samples of closely related species, i.e., mule deer from white-tailed deer, buffalo (*Bison bison*) from beef (*Bos bos*), bighorn sheep (*Ovis canadensis*) from domestic sheep (*O. aries*), grizzly (*Ursidae horribilis*) from black bear (*U. americanus*); 2) the ability to match individual blood, hair, or tissue samples to individual animals; 3) the ability to consistently detect game meat in cooked and processed meat, i.e., summer sausage; 4) to determine how long meat has been stored in a freezer; 5) accurate determination of time of death in a given animal; 6) determination of sex of an animal from dried blood, tissue, or hair; 7) identify detached head with carcass or separate quarters as from the same animal; 8) wound test for the presence of lead, i.e., development of a more reliable a field test.

Thirteen years after the Alberta FSS many of these wildlife forensic problems have been solved; other problems remain unsolved and some never will be solved. In the meantime, new problems not visualized in 1977 have materialized.

Methods have been developed and completed which currently allow the identification of closely related species (e.g., mule deer from white-tailed deer) by immunoelectrophoresis (Oates et al. 1974, 1976) and isoelectric focusing (Harvey et al. 1987, Oates et al. 1979), and starch get electrophoresis for identifying different waterfowl species (Oates et al 1983).

The ability to consistently detect game meat in cooked or processed meats has developed to the point that white-tailed deer and mule deer can be consistently detected in samples which have been heated to ≥67°C. Heating above 67°C. provides unreliable results. Also, pork and buffalo can be differentiated from all other species, and deer, pronghorn (*Antilocapra americana*), moose (*Alces alces*), and sheep can be differentiated from beef, elk (*Cervus canadensis*), red deer (*C. elaphus*), and caribou (*Rangifer caribou*) (McCormick et al. 1988).

The determination that a specific piece of meat has been frozen can be made because of various physiological factors such as lysising of red blood cells, enzyme changes, freezer burn, etc.; however, determination of the length of time frozen remains elusive. Wyoming's Game and Fish Department has spent 2 years studying the chemical and physical changes in game meat due to freezing. Their final conclusions were that they could tell if the meat had been frozen but the length of time frozen was inconclusive. Various factors affect the results for length of time frozen, such as type of freezer, efficiency of freezer, temperature setting of freezer, how well the meat is wrapped, and even if the electricity has been off to the freezer for a period of time (Morgan-Renk 1987, T.D. Moore, pers. commun.).

The ability to estimate time of death in wildlife species is a skill greatly desired by law enforcement personnel (Beattie and Giles, 1979). It can be critical to a wildlife officer whether a deer was killed during the early hours of open season or the night before, since it is not uncommon to have a deer checked in that was killed the day before the season opened (Oates 1984). The ability to determine time of death also allows the wildlife officer to detect deer taken by spotlight and claimed to have been killed during the late afternoon.

In species other than white-tailed deer, time of death determination allows wildlife officers to determine if rabbits (Hoilien 1974) have been taken at night as opposed to daylight hours and if waterfowl bag limits have been rearranged, when taken under the point system. Limited time of death literature is also available for pheasants, bear, moose, elk, and mule deer (Reed and Bowden 1974, Denney 1977, Oates et al. 1984).

More research on time of death in white-tailed deer has been conducted than any other species because of its widespread distribution and increasing populations which results in increased poaching (Gill and O'Meara 1965, Woof and Gremillion-Smith 1983, Woolf et al. 1983, Oates et al. 1984, Stockdale, unpubl. data). The traditional methods for time of death determination (i.e., thigh and nasal temperatures, pupil diameter, electrical stimulus, and rigor mortis) are not always 100% accurate. Thigh temperature, nasal temperature, and pupil diameter are objective findings; however, electrical stimulus and rigor mortis are subjective findings and vast differences may be recorded in the latter 2 because of the tester's training and experience. Although all the above criteria should be used whenever possible to determine time of death, Gill and O'Meara (1965) recognized the thigh temperature as being the single most accurate indicator of time of death in white-tailed deer.

The 1970s and 1980s saw the personal computer make its debut in wildlife forensics. Kienzler and Fuller (1983, 1989) used modern statistical analysis to analysis Gill and O'Meara's work to develop a computer program for time of death determinations in white-tailed deer using thigh temperature. The program uses thigh temperature, air temperature, and field-dressed weight to generate minimum-maximum time of death estimates at the 0.95 percentile.

Kienzler's computer model and traditional methods for determining time of death in white-tailed deer were used in Tennessee to examine 1,200 hunter harvested deer with known time of death (i.e., ±30 minutes or ±15 minutes), and 404 observations made on 32 deer with exact time of death known. All 1,604 observations fell within the computer's minimum-maximum time frame with 45.7% within ±30 minutes and 71.2% within ±60 minutes of the computer's estimated actual time of death (Stockdale, unpubl. data).

In actual field cases in Tennessee during the past 2 years, it has been found that many suspect deer examined have not been field-dressed; therefore, the thigh temperature and computer program could not be used. The wildlife officers in these situations used other traditional methods for determining time of death.

One area of wildlife forensics long overlooked until the 1970s and 1980s is comparative osteology. The identification of a detached head, quarter, or other part of an animal can often be made by comparative osteological characteristics and or x-rays to match cut and broken bones. Comparative osteology can often be used to determine that a particular head did not come from a specific animal due to an excessive number of cervical verterbra. Comparative osteology can also be used to determine the minimum number of animals in a sample.

Modern day research in comparative osteology indicates that nearly every bone in an animal is probably sexually dimorphic and that species and sex can be determined from them. The problem is that sufficient research has not been done on most animals and that each geographic area (i.e., state or even sub-parts of states) must be analyzed and a data base established for that particular animal.

During the 1980s comparative osteology has expanded the wildlife forensic ability to accurately sex white-tailed deer and other big game animals using the pelvic girdle. Early works by Tabor (1956) allowed sexing by the pelvic girdle accurately only in specimens ≥ 2.5 years old. Edwards et al. (1982) expanded this work and lowered the age to 1.5 years. Additional work by Purdue and Jacobs (1987) now allows the officer to observe 5 different areas of the pelvic girdle to determine sex on specimens down to 1.0 year. This technique is especially helpful to the officer in the field who encounters a headless carcass, a carcass who's head is damaged beyond recognition, or the carcass hanging in a meat locker.

Work by Haspel and Walker (1987) and Miller et al. (1987) in Wyoming has resulted in other osteological features, exclusive of the head, which may be used to sex big game species or to separate closely related species when the head is missing. Current research in progress includes elk, mule deer, and white-tailed deer in Colorado, Wyoming, and Tennessee which will allow sex and species to be determined using various leg bones.

The testing of suspect bullet wounds, especially in big game animals during archery only season, for the presence of copper and/or lead residue is a field test which the wildlife officer can use to obtain presumptive evidence allowing him to seize an animal (Feigl 1958, Hagg 1981, Glover 1981, Stockdale 1989a). Once the animal has been seized, hide and tissue samples can be forwarded to the laboratory for atomic absorption spectrophotometric analysis to provide conclusive evidence of copper and or lead residue indicating an animal was shot with a firearm as opposed to an arrow (Stockdale 1989*a*).

Unfortunately, the ability to match individual blood, tissue, or hair to an individual animal, determine sex of an animal from blood, tissue, or hair, or to positively identify all detached parts of a carcass to a specific carcass are either not possible today or not possible in all cases. However, because of DNA fingerprinting the ability to complete these objectives "tomorrow" will be a reality.

One group responsible for the increased interest in wildlife forensics is the Midwest Association of Fish and Game Officers. Each year they conduct officer workshops in covert investigations, training, and wildlife forensics. The meetings not only provide a forum for wildlife forensic specialists to exchange ideas but to also discuss new areas of concern for forensic research.

The Midwest Association began compiling articles on wildlife forensics and assembled them into what became known as the "Blue Books." The techniques contained in the Blue Books currently cover several volumes and are provided to all member states and provinces of the Midwest Association. The Midwest Association also has provided grant money to various wildlife forensic researchers to develop many of the techniques discussed in this paper.

Following a meeting of wildlife forensic specialists in 1988 at the Midwest Association meeting in Kansas City, Kansas, the Midwest Association decided to publish a manual on wildlife forensic techniques. Dr. William Adrian, Colorado Division of Wildlife, has edited this manual which will be called the "Green Book." The publication should be available in 1990 and will consist of a pocket-size ring binder with all printing and drawings on waterproof paper. Some of the topics covered include time of death, sexing the headless carcass, metal detectors, evidence collecting and packaging, and breastbone identification of waterfowl, turkey, and pheasants.

The creation of new problems and the renewal of old problems in the 1980s has resulted in wildlife forensics providing new methods and expanding on old methods to aid the wildlife officer in solving problems not visualized at the Alberta FSS. Several new wildlife forensic procedures have been developed during the 1980s which allow the wildlife officer to obtain probable cause to arrest a person and or seize an animal.

Declining waterfowl populations and the mandated change from leadshot to non-toxic shot have created additional enforcement problems for wildlife officers. Wildlife forensics was able to use modern technology during the 1980s to develop a specialized forensic metal detector which could differentiate between lead shot and steel shot. This instrument allows the wildlife officer to determine in the field if a duck or goose has been shot with lead shot or steel shot (Stockdale 1989*b*).

The use of the point system during the 1970s and 1980s created special problems for officers, especially on those species of waterfowl which carried a high point value or which the season was closed. Many hunters would breast a bird out; thereby claiming a canvasback was a mallard and take the chance on getting caught and paying a small fine for not leaving the wing or head attached to the bird as opposed to paying a large fine for killing a bird in closed season or exceeding the bag limit. Comparative osteology has now made it possible to identify waterfowl by the breastbone with the meat intact (Meints and Oates 1987, Oates 1988). With proper training and experience the officer should be able to identify all ducks as either puddle ducks or divers, to genus, and many of the more common ducks to species and establish probable cause in the field to seize the birds. Once the birds have been seized, additional measurements can be taken in the laboratory to determine species.

Oates has also used comparative osteology to differentiate the sex of pheasants when breasted out (Oates 1985) and the differentiation of wild turkey (*Meleagris glllopavo*) versus domestic turkey and the sex of wild turkey by the breastbone (Oates 1986).

The Future

Advances in wildlife forensics during the 1990s should eclipse the past 90 years of wildlife forensics combined. The development of DNA fingerprinting (Jeffreys et al. 1985) and its application to wildlife forensics will provide wildlife law enforcement with its most valuable tool next to the wildlife officer in the field. DNA fingerprinting will answer the remaining solvable problems from the Alberta FSS; namely, the matching of individual blood, tissue, and or hair samples to individual animals, determination of sex of an animal from dried blood, tissue, or hair, and the positive matching of carcass parts to a particular carcass, blood, or hair sample.

Although DNA fingerprinting is in its infancy with animals, various wildlife agencies and universities are conducting research which will aid the wildlife law enforcement officer in his work. While much of the current DNA fingerprinting is directed at big game species (Thommason et al. 1989, T.D. Moore, pers. commun.) other wildlife agencies and universities are developing the same DNA fingerprinting techniques for fish.

A major advancement for wildlife forensics in the 1990s is the opening of the National Fish and Wildlife Forensics Laboratory (NFWFL) in Ashland, Oregon, by the United States Fish and Wildlife Service. Although this facility only opened in 1989 and is still being staffed and equipped, the potential for wildlife law enforcement forensic science is exceptional. The NFWFL is currently composed of 4 sections: criminalistics, morphology, evidence and property control, and technical support.

Criminalistics Section

The criminalistics section will be responsible for using analytical methods or developing analytical methods where none exist to perform the following functions: identification of carved ivory objects (i.e., elephant ivory and African or Asian elephant versus Mammoth or Mastodon); aging of ivory objects (i.e., carved ivory objects would be examined to determine time of death of the source animal); aging of miscellaneous biological materials (i.e., miscellaneous biological materials would be aged to the time of death of the source animal); identification of pesticides in water, soil, or food; identification of pesticides in tissue; identification of poisons in water, soil, or food; identification of poisons in tissue.

The criminalistics section would develop and use DNA fingerprinting for the identification of threatened species blood and tissue samples, identification of individual raptors via DNA blood typing, and identification of individual raptors via DNA blood typing, and identification of individual animals via DNA blood typing.

Morphology Section

The morphology section is responsible for the identification of whole bird carcasses (duck and geese) using identification by bone structure when the carcasses lack feathers or other outwardly identifiable characteristics. Also, the identification of teeth and claws to determine the species involved.

Evidence and Property Control Section

In addition to receiving all evidence shipped and delivered to the laboratory, this section will be responsible for processing items for latent prints, identification of latent prints to a known suspect's prints, and crime scene investigation services.

The crime scene investigating services would be composed of a highly qualified team of crime scene investigators who would respond to a specified crime scene for the purpose of documenting the scene, collecting evidence, and linking together suspect, victim, and crime scene.

Technical Support Section

The technical support section will handle the film processing services, negative printing services, video and audio tape duplication, and surveillance services.

The surveillance service would consist of a highly qualified team of forensic specialists who would respond to a specified scene for the purpose of using advanced photo/video equipment and techniques to document illegal activities on the part of suspect wildlife law violators.

Conclusions

Because of additional duties consistently being placed on the multipurpose wildlife officer and the reduced hours he can work because of the Garcia decision, administrators and supervisors must seek all available methods to aid the wildlife officer in the work effort. Wildlife forensics can provide valuable scientific analysis for wildlife law enforcement cases. Wildlife forensics can, and often does, provide the difference in a suspected poacher going free or being convicted.

Wildlife officers should remember that all wildlife forensic techniques are not suitable for use in the field, and they must keep this in mind and not attempt to use techniques designed for laboratory use in the field. Wildlife officers or specialists must receive an initial training period in any wildlife forensic technique, build experience using it, document this training and experience, and undergo additional training to maintain expertise as an expert witness.

"Tomorrow" is almost here. The rest of the world has moved into the Space Age. Wildlife law enforcement has moved from the Stone Age to the 20th century. Now is the time for wildlife law enforcement, through wildlife forensics, to move into the Space Age. The only question remaining for administrators and supervisors is, "Where are we going to find the time and money?"

Literature Cited

Alberta Recreation, Parks and Wildlife. 1977. Proceedings of the forensic science symposium. Alberta Recreation, Parks and Wildl., Calgary, Alberta, Can. 321pp.

Beattie, K.H. and R.H. Giles. 1979. A survey of wildlife law enforcement research needs and current research. Wildl. Soc. Bul. 7:185–188.

Brohn, A. and L.J. Korschgen. 1950. Precipitin test—a useful tool in game law enforcement. Trans. North Am. Wildl. Conf. 15:467–468.

Brunner, H. and B.J. Coman. 1974. The identification of mammalian hair. Inkata Press, Melbourne, Australia. 176pp.

Clarke, F.D. 1914. Forensic value of the precipitin test in the enforcement of game laws in California. Univ. Calif. Publ. Pathol. 2:131–138.

Denney, R.N. 1977. Post-death elk carcass temperature changes. 1977 Guidelines. Regular Deer and Elk, Col. Dep. Nat. Resour., Div. Game, Fish, and Parks. Pages 81–84.

Edwards, J.K., R.L. Marchinton, and G.F. Smith. 1982. Pelvic girdle criteria for sex determination of white-tailed deer. J. Wildl. Manage. 46:544–547.

Feigl, F. 1958. Spot tests in inorganic analysis. Elsevier Publ., New York, N.Y. 600pp.

Fenstermacher, R. and B.S. Pomeroy. 1938. Identification of suspected beaver blood stains. Cornell Vet. 28(3):257–260.

Gay, F.P. 1908. A contribution to the forensic value of the musculo-precipitin test. J. Med. Res. 19(1):219–224.

Gill, J.D. and D.C. O'Meara. 1965. Estimating time of death in white-tailed deer. J. Wildl. Manage. 29(3):471–486.

Glover, R.L. 1981. Detecting lead in arrow wounds in deer using rhodizonic acid. Wildl. Soc. Bul. 9:216–219.

Grabar, P. and C.A. Williams. 1953. Methode immuno-electrophoretique d'analyse de melanges de substances antigenques. Biochimica et Biophysica Acta 10:193–194.

Haspel, H. and D.N. Walker. 1987. Final report: Assessment of sexual dimorphism in Rocky Mountain Bighorn sheep. Wyo. Game and Fish Dep., Univ. Wyo., Laramie 13pp.

Harvey, W.E., L.T. Fries, and L.S. Brooks. 1987. A forensic program for identification of fish and wildlife species. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 41:485–492.

Haag, L.C. 1981. A microchemical test for copper-containing bullet wiping. J. Assoc. Firearm and Toolmark Examiners 3:22–28.

Hoilien, G.I. 1974. A study of the variation of reaction to electrical stimulus after death. Iowa Conserv. Comm., Law Enforcement Res. 8pp.

Jeffreys, A.J., V. Wilson, and S.L. Thein. 1985. Individual specific fingerprints of human DNA. Nature 316:76–79.

Keer, K.D. 1986. Sex identification of white-tailed deer using frozen venison. J. Forensic Sci. 31(3):1108–1112.

Kienzler, J.M. and W.A. Fuller. 1983. Estimation of time since death in white-tailed deer based on thigh temperature. Iowa Wildl. Res. Bul. 35. Iowa Conserv. Comm. 38pp.

——— and ———. 1989. Estimation of time since death in white-tailed deer based on thigh temperatures: a manual. Iowa Dep. Nat. Resour., Des Moines 25pp.

Mayer, W.V. 1949. The comparative anatomy of the hairs of California mammals. Ph.D. Thesis, Stanford Univ., Stanford, Calif. 392pp.

———. 1952. The hair of California mammals with keys to the dorsal guard hairs of California mammals. Am. Midland Nat. 38:480–512.

McCormick, R.J., T.D. Moore, R.A. Field, and W.G. Hepworth. 1988. Identification of deer meat in cooked products. Wildl. Soc. Bul. 16:433–436.

Meints, D.R., and D.W. Oates. 1987. Sexing field-dressed mallards. Neb. Wildl. Bul. 87-1. Neb. Game and Parks Comm., Lincoln.

Miller, K.G., D.F. McKee, and D.N. Walker. 1987. Final report: Analysis of selected post-cranial skeletal elements for *Odocoileus hemionus* and *Odocoileus virginiaus*. Wyo. Game and Fish Dep., Univ. Wyo., Laramie. 14pp.

Moore, T.D., L.E. Spence, and C.E. Dugnolle. Identification of the dorsal guard hairs of some mammals of Wyoming. Wyo. Game and Fish Dep., Bul. 14, Cheyenne. 177pp.

Morgan-Renk, L. 1987. Chemical and physical changes in game meat due to freezing. Wyo. Game and Fish Dep. Progress Report, June. 51pp.

Oates, D.W. 1986. Identification of turkey breast bones. Neb. Game and Parks Comm., Lincoln. 1p.

———. 1988. Identification of duck breast bones in birds of the central flyway. Neb. Game and Parks Comm., Lincoln. 4pp.

———, C.W. Brown, and D. L. Weigel. 1974. Blood and tissue identification of selected birds and mammals. Neb. Game and Parks Comm., Lincoln. 105pp.

———, J.L. Coggin, F.E. Hartman, and G.I. Hoilien. 1984. A guide to time of death in selected wildlife species. Neb. Tech. Ser. 14, Neb. Game and Parks Comm., Lincoln. 72pp.

———, N.L. Dent, and K.A. Pearson. 1979. Differentiation of white-tailed and mule deer tissue by isoelectric focusing. Wildl. Soc. Bul. 7:113–116.

———, G. I. Hoilien, and R.M. Lawler. 1985. Sex identification of field-dressed ring-necked pheasants. Wildl. Soc. Bul. 13:64–67.

———, J.E. Seeb, L.N. Wishard, and P. Abersold. 1983. Biochemical identification of North American waterfowl. Neb. Tech. Ser. 13, Neb. Game and Parks Comm., Lincoln. 68pp.

——— and D.L. Weigel. 1976. Blood and tissue identification of selected birds and mammals: part II. Neb. Game and Parks Comm., Lincoln. 118pp.

Ouchterlony, O. 1948. In vitro method for testing the toxin-producing capacity of diphtheria bacteria. Acta Pathol. Microbiol. Scand. 25:186–191.

———. 1968. Handbook of immunodiffusion and immuno-electrophoresis. Ann Arbor Sci., Ann Arbor, Mich. 215pp.

Purdue, J.R. and C.L. Jacobs. 1987. Sexual characteristics of the pelvis of white-tailed deer. Manuscript on file, Ill. State Museum, Springfield, Ill. 13pp.

Reed, D.F. and D.C. Bowden. 1974. Postmortem thigh temperatures in mule deer. Colo. Dep. Nat. Resour., Div. of Game, Fish and Parks, Game Inf. Leafl. 98. 2pp.

Stockdale, M. 1989*a*. Forensic procedures manual. Tenn. Wildl. Resour. Agency, Nashville, Tenn. 68pp.

———. 1989*b*. Forensic metal detectors for nontoxic shot enforcement in migratory waterfowl. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies. 43:515–522.

Tabor, R.D. 1956. Characteristics of the pelvic girdle in relation to sex in black-tailed and white-tailed deer. Calif. Fish and Game 42:15–20.

Thommasen, H.V., M.J. Thomson, G.G. Shutler, and L.T. Kirby. 1989. Development of DNA fingerprints for use in wildlife forensic science. Wildl. Soc. Bul. 17:321–326.

Wildman, A.B. 1954. The microscopy of animal textile fibres. Wool Industry Res. Assoc., Leeds, Eng. 209pp.

———. 1961. The identification of animal fibers. J. Forensic Sci. Soc. 1(2):1–8.
Woolf, A. and C. Gremillion-Smith. 1983. Using vitreous humor to determine time of death: problems and a review. Wildl. Soc. Bul. 11:52–55.
———, J.L. Roseberry, and J. Will. 1983. Estimating time of death of deer in Illinois. Wildl. Soc. Bul. 11:47–51.