THE COTTONMOUTH OR WATERMOCCASIN, *AGKISTRODON PISCIVORUS* (LACEPE) PART IV OF IV

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VENOM

■ Yield

In order to obtain the venom necessary for toxicity studies, antivenin production and medical purposes, venomous snakes are subjected to the extraction process known as "milking". The yields from the extractions are given as either a liquid volume (cc or ml. of fresh venom) or as a dried weight (in mg) after freeze-drying or dessication.

Venom yields for water moccasins (from young specimens to adults) have been given many times, with a range from 0.32 - 2.50 cc (80-300 mg). Listed below are some of the yields given by various authors followed by the two highest yields thus far recorded for the species.

Amaral (1928):
young specimens - 0.32 cc/90 mg,
adults - 0.42 cc / 120 mg,
old adults - 0.53 cc / 150 mg
exceptional adults - 1.05 cc / 130 mg

Wolff and Githens (1939b):
0.55 cc / 158 mg (an average taken from 315 snakes. over a two year period, the range was 0.333 – 0.777 cc / 80 - 237 mg).

Allen and Swindell (1948): average yield 0.8 cc, largest yield - 2.5 cc

Agkistrodon piscivorus Photo by Arne Bakker.

Brown (1973): average yield 125 mg (range from 80 - 237 mg).

Minton (1980): average adult specimen 100 - 150 mg

Russell (1983): average yield 90-170 mg, (using data supplied by Ross Allen).

Phelps (1984): average yield 80 - 180 mg

To date, the two largest venom yields from a cottonmouth are those reported by Wolff and Githens (1939a). A large male, measuring 60 inches in total length, yielded 4.0 cc of venom with a dried weight of 1.094 grams. Five weeks earlier, the same snake yielded 3,5 cc of venom, having a dried weight of 947 mg The yield of 4.0 cc is just over seven times the average yield of 0.55 cc reported by Wolff and Githens (1939b).

■ Potency

The LD_{50} (lethal dose 50% or lethal median dose) is probably the most useful and widely used method for determining the lethality of snake venom. Russell (1983) defined it as "that dose of venom or venom component that kills 50 percent of a given group of animals". The most commonly used test animals are mice, although young rats and pigeons are also used. A group of animals, ranging in number from 4 - 100, is injected with known quantities of a particular venom under laboratory conditions. These dosages range from "the minimum amount that kills all animals in a: group to the maximum amount that kills none" (Russell, 1983). Statistics can then be used to calculate the LD_{50}-value, which is a useful tool when comparing the venom of different species of snakes. When using these values it is important to state the route of injection used (subcutaneous, intraperitoneal, or intravenous) because each of these can result in extremely different LD_{50}-values, with the intravenous route giving the lowest. Once determined, these values are reported as either milligram./kilogram, or as milligrams (occasionally micrograms) / exact animal weight. Results given as mg/kg. can be converted to mg by multiplying the number by the weight of the test animal, then dividing by 1000.

Several authors have supplied LD_{50}-values for cottonmouth venom over the years, a few of which are listed below.

Minton (1980) listed an intravenous LD_{50}-value of 80 micrograms (0.08 mg) for 20 gram mice. Brown (1973) supplied LD_{50}-values ranging from 1.1 - 4.0 mg/kg., but did not give the weight of the test mice. If an average adult mouse is considered to weigh approximately 20 grams, the values given by Brown can be calculated to be between 0.02 - 0.08 mg Russell (1983), using data supplied by Ross Allen, reported an intravenous LD_{50}-value of 4.17 mg/kg. for mice weighing 20 grams. If calculated for the body weight of the mice the LD_{50}-value would be 0.083 mg, almost identical to that given by Minton (1980).

Another, less popular method for determining the lethality of snake venom is the MLD or minimum lethal dose. Githens and Butz (1929) defined this as "the smallest quantity, expressed in milligrams of venom, which will kill a pigeon of 350 gram weight, injected intravenously". Githens and Butz (1929) and Githens (1931) both reported an MLD value of 0.10 mg for cottonmouth venom. Wolff and Githens (1939b) listed the

results from a series of 16 extractions which totaled 315 snakes. The average MLD value from this study was given as 0.09 mg These same authors tested the venom from the two record yields' mentioned earlier in this paper. The MLD values for these two yields (4.0 and 3.5 ml.) were found to be 0.07 and 0.06 mg respectively.

Often times, the potency of the venom from juvenile snakes it questioned. In the past some people have suggested that juveniles either possess an extremely weak venom, or lack it altogether. Research though has shown that the potency of venom from young snakes is usually equal to, and sometimes greater than, that of an adult. Allen and Swindel (1948) stated that the venom extracted from eleven, one week old cottonmouths "was found to be more potent than that off adult snakes".

THE BITE

■ Effects

The destructive or necrotizing effect that.cottonmouth venom has on tissue is well known. Minton (1980) gives an excellent description of these effects; "Cottonmouth venom literally dissolves the tissue that it contacts. Small blood vessels are disrupted so that the blood leaks out. As the zone of vascular damage increases in size, the animal bleeds to death into its own tissues. The heart fails, not because of direct injury, but because it can no longer pump effectively through the riddled vascular bed".

Additional damage can occur as the result of gangrene, which often times is a result of cottonmouth bites. Allen and Swindell (1948) stated "Our records show that fifty percent of moccasin bites result in crippled fingers or toes, due to gangrene which usually sets in as a result of coagulation, destruction of red corpuscles and strangulation of blood vessels".

Other symptoms that have been recorded as a result of moccasin envenomation include; edema, ecchymosis, pain, weakness, nausea, sloughing of skin around bite area, unconsciousness and respiratory difficulty.

■ Factors affecting seriousness

Many factors affect the severity and final outcome of a snakebite, a few of which include;

- health of the snake,
- amount and potency of venom injected,
- size of the snake,
- health and size of the victim,
- location of the bite,
- the elapsed time between the bite and the administration of antivenin.

The amount of venom injected is highly variable and is controlled by the snake. Dry bites, bites in which no venom is injected, have been reported to account for up to 30% (possibly 50%) of the snakebites in this country. This statistic, comforting as it may seem, should not be used as justification to keep a snakebite victim from receiving prompt medical attention.

■ Frequency of Bites in the U.S.

Cottonmouths have been reported to account for approximately 10% of the snakebites that occur each year in the United States (Caras, 1974; Githens, 1935). Parrish (in Russell, 1983) determined that cottonmouths were responsible for 7.3% of. the 2,836 snakebite cases that he reviewed. Detailed accounts of annual snakebite cases and the species involved have been published. Hutchinson (1929, 1930) gave such accounts for the

calendar years' 1928 and 1929, respectively. In these, he included tables containing the number of snakebites that occurred each week and the species involved. Cases in which the identification of the snake was not known, or was questionable, were included under columns headed "Rattlesnake spp." or "Species undetermined" (Hutchinson 1929, 1930). From the data that were presented in these tables, it can be calculated (in those cases where the snakes' identity was known) that Cottonmouths were responsible for 9.4% of the snakebites in 1928 'and 9.6% in 1929.

■ Fatalities

Fatalaties from cottonmouths bites, while not common, do occur. It has been estimated that the lethal dose for an adult is approximately 100 mg (Minton, 1980 and Phelps, 1984).

The mortality rate (number of deaths / total number of bites) for moccasin bites has been given as 0.13% by Parrish (in Caras, 1974). Allen and Swindell (1948) supplied information on cottonmouth bites that were recorded in Florida from 1934 – 1944. A total of 68 bites occurred, resulting in 3 fatalaties. The morality rate for this 11 year period would be 4.4 %. It should be pointed out though, that all three deaths occurred in 1934. Since only eight bits were reported for that year, the morality rate would be 37.5 %.

SUSCEPTIBILITY OF SNAKES

The affect that a snake's venom has on itself as well as on snakes of the same or different species has been a rather controversial subject for many years. Some people may believe that a venomous snake is immune to its own venom. (or that of a conspecific), but not that of another species. Others may believe that they are immune to all types of venom. In addition, it is often said that colubrid snakes, such as kingsnakes, are immune to snake venom.

The main problem is determining whether or not venom was injected into the bitten snake. A snake could receive a dry bite, therefore showing non sign of envenomation. This could then be misinterpreted as an indication of immunity on the part of the victim.

Many literature accounts can be found of venomous snakes inflicting bites upon other snakes. The results of these bites can range from no effect, to death within a few hours. Specific cases involving cottonmouths and other venomous snakes are given below.

Munro (1947) reported on a female Sistrurus miliarius streckeri that bit a small male Crotalus horidus horridus. The bite was at mid-body and resulted in no apparent ill-effects. The author summarised this incident as follows: "If, as seems likely from the vigour of the bite and from the Pigmy Rattler's customary readiness: to inject venom, a. normal amount of poison had been injected into the considerably smaller Timber Rattler, it is evident that the venom of the Pigmy Rattler does not have serious effects on the Timber Rattler". Fitch (1960) stated that the effects observed from copperheads biting other copperheads ranging from "no perceptible effect at one extreme, to almost instantaneous collapse and death within a few minutes at the other".

Gloyd (1933) reported on a 4 ft. Western diamondback that was bitten by a 2.5 ft. cottonmouth on November 18, 1932. By the following morning, the only symptoms that were evident, were swelling and discoloration of the skin at the

Agkristrodon contortrix Photo by Arne Bakker.

site of the bite. By the third day after the bite, the diamondbacks' condition had worsened, leading eventually to its death. A post-mortem examination of the bite area revealed signs of envenoumation that included "extravasation of blood and lymph, and evidence of general histolysis in all tissues of the body wall" (Gloyd, 1933). Additional, tissue destruction was found along the body cavity, and the lung was filled with blood that did not coagulate.

Conant (1934) reported on a 2.5 ft. cottonmouth that had bitten a 26 inch northern pacific rattlesnake Crotalus viridis oreganus at a point anterior to the base of the tail. The oreganus died approximately five hours after the bite and showed marked edema in the area of the bite, as well as discoloured muscle tissue and sloughing of the skin. The left kidney was also affected, appearing "swollen and deep purple in colour" (Conant, 1934). A few days later the same cottonmouth was found swallowing another Crotalus viridis oreganus. The snake was still alive when it was disgorged but died several hours later. At this time the head and neck area were greatly swollen and the tissue was purplish in colour.

Detailed studies on the effects of snake venom upon different species of snakes have been performed under laboratory conditions by numerous authors including Nichol, Douglas and Peck (1933), Allen (1937), Keegan and Andrews (1942), Swanson (1946) and Sanders (1951). In these experiments snakes were either forced to bite themselves, or were injected with varying doses of venom. The venom from several different types of snakes was used, including that from copperheads, cottonmouths, diamondbacks, timber rattlesnakes and massasaugas. Recipient snakes included boids, colubrids and crotalids. In these studies the effects that the venoms had, as well as the final outcome were recorded. Results ranged

from no observable symptoms in some cases, to death within a few minutes or a few days in a large percentage of the others.

CONCLUSION

It is hoped that from this article the reader will have increased his knowledge and appreciation of the cottonmouth Agkistrodon piscivorus. These snakes, while potentially dangerous, are a fascinating species possessing many interesting characteristics and habits. Breen (1974) stated: "Even the most ardent snake admirer would not call the water moccasin a pretty reptile". I would have to disagree with Breens' statement, as I find that cottonmouths, especially juveniles, are one of the most attractive crotalids in the United States.

The bibliography of this article is divided into literature cited and suggested reading sections. While by no means exhaustive, these sections are somewhat extensive. It is hoped that through this bibliography, some readers will become aware of the numerous sources available for obtaining information on any reptile or amphibian.

LITERATURE CITED

Allen, E. R. (1937). *Florida snake venom experiments.* Florida Acad. Sci., 2: 7 pp.

Allen, E. R. (1949). *Observations of the feeding habits of the juvenile cantil.* Copeia, 1949(3): 225 - 226.

Allen, E R and Swindell, D. (1948). *Cottonmouth moccasin in Florida. Herpetologica,* 4(1): 1 - 16 (first supplement).

Allen, J. M. J. (1932). *A survey of the amphibians and reptiles of Harrison County,* Mississippi. Amer. Mus. Novit. 542: 1 - 20.

Amaral, A. D. (1928). *Studies on snake venoms. I. amounts of venom secreted by nearctic pit vipers.* Bull. Antivenin Inst. Amer. 103 - 104.

Anderson, P. (1941). *The cottonmouth in northern Missouri.* Copeia 1941: 178.

Anderson, P. (1945). *New herpetological records.for Missouri.* Bull. Chicago Acad. Sci. 7 (5): 271 - 275.

Anderson, P. (1965). *The reptiles of Missouri.* Univ. Missouri Press, Columbia, xxiii 330 pp.

Arny, S. A. (1948). *A survey of the reptiles and amphibians of the Delta National Wildlife Refuge. Master's thesis.*(unpublished). Tulane University, New Orleans, La.

Ashton, R. E. and Ashton, P. S. (1981). *Handbook of reptiles and amphibians.of Florida. Part one, the snakes.* Windward Publishing, Inc. Miami, 176 pp.

Ashton, R. E. and Collins, J. T. (1974). *Rare, endangered and extirpated species in Kansas. II. Amphibians and reptiles.* Trans. Kansas Acad. Sci. 76 (3): 185 – 192.

Baird, S. F. and Girard, C. (1853). *Catalogue.off North American Reptiles in the museum of the Smithsonian Institution. Part one, serpents.* Washington, Smithsonian Institution, xvi 172pp.

Baker, R. E. (1983). *The western cottonmouth in Osage County, Oklahoma.* Bull. Oklahoma Herp. Soc. 8 (2): 56 - 57.

Baker, R. E. (1985). *Late season capture of the western cottonmouth, Agkistrodon piscivorus leucostoma, in northern Osage County, Oklahoma.* Bull. Oklahoma Herp. Soc. 10 (3-4): 23.

Barbour, R. W. (1956). *A study of the cottonmouth, Agkistrodon piscivorus leucostoma Troost in.Kentucky.* Trans. Kentucky Acad. Sci. 17 (I): 33 - 41.

Barbour, R. W. (1971). *Amphibians and reptiles of Kentucky.* Univ. Press of Kentucky, Lexington. 334pp.

Bart, H. L. and Hoover, J. J. (1984). *Delaware County records for the western cottonmouth.* Bull. Oklahoma Herp. Soc. 9 (4): 35.

Beauvois, P. D. (1799). *Memoir on amphibia, serpents.* Trans. Amer. Philos. Soc. 4: 362 - 381, 1 pl.

Behler, J. L. and King, F. W. (1979). *The Audobon Society field guide to North American reptiles and amphibians.* Alfred A. Knopf, New York. 719pp.

Beyer, G. E. (1898). *Contributions on the life histories of certain snakes.* Amer. Nat. 32: 17 - 24.

Blaney, R. M. (1971). *An annotated check list and biogeographic analysis of the insular herpetofauna of the apalachicola region, Florida.* Herpetologica 27 (4): 406 - 430.

Blem, C. R. (1981). *Reproduction of the eastern cottonmouth Agkistrodon piscivorus (Serpentes; Viperidae) at the northern edge of its*

Brimlyana 5: 117 - 128.
Blem, C. R. (1982). *Biennial reproduction in snakes: An alternative hypothesis.* Copeia 1982 (4): 961 - 963.
Bothner, R. C. (1974). *Some observations on the. feeding habits of the cottonmouth in southeastern Georgia.* Journal of Herpetology 8 (3): 257 - 258.
Bowler, J. K. (1977). *Longevity of reptiles and amphibians in North American collections as of 1 November, 1975.* SSAR Herp. Circ. 6:iv 32.
Breen, J. F. (1974). *Encyclopedia of reptiles and Amphibians.* T.F.H. Publications Inc., Neptune City, New Jersey, 576pp.
Brimley, C. S. (1944). *Amphibians and reptiles of North Carolina.* Carolina Biological Supply Co., 63p. (reprinted from Carolina Tips 1939 - 1943).
Brown, J. H. (1973) *Toxicology and pharmacology of venom from poisonous snakes.* Charles C. Thomas Publisher, Springfield, Illinois, xiv 184 pp.
Brown, R. W. (1954) *Composition of scientific words.* (1978 reprint). Smithsonian Institution Press, Washington D. C. 882pp.
Burger, W. L. and Smith, P. W. (1950). *The coloration of the tail tip of young fer-de-lances: sexual di-morphism rather than adaptive coloration.* Science 112: 431 - 433.
Burkett, R. D. (1966). *Natural history of cottonmouth moccasin Agkistrodon piscivorus (Reptilia).* Univ. Kansas Publ. Mus. Nat. Hist. 17 (9): 435 - 491.
Capron, M. (1984). *The cottonmouth in Kansas.* Kansas Herp. Soc. Newsletter 58: 9 - 11.
Caras, R. A. (1974). *Venomous animals of the world.* Prentice-Hall Inc., Englewood Cliffs, New Jersey. :xix 362pp.
Carpenter, C. C. (1958). *Reproduction, young, eggs and food of Oklahoma snakes.* Herpetologica 14 (3): 113 - 114.
Carpenter, C. C. and Gillingham, J. C. (1975). *Postural responses to kingsnakes by crotaline snakes.* Herpetologica 31 (3): 293 - 302.
Carpenter, C. C., Murphy, J. B. and.Carpenter, G. C. (1978). *Tail luring in the death adder, Acanthophis antarcticus (Reptilia, Serpentes, Elapidae).* Journal of Herpetology 12 (4): 574 - 577.
Carr, A, F., Jr., and Carr, M. H. (1942). *Notes on the courtship of the cottonmouth moccasin.* Proc. New England Zool. Club, (July 18) 20: 196.
Clark, R F. (1949). *Snakes of the hill parishes of Louisiana.* Journal Tennessee Acad. Sci. 24 (4): 244 - 261.
Cliburn, J. W. (1976). *A key to the amphibians and reptiles of Mississippi.* Fourth edition. State Wildlife Museum, Jackson, Mississippi, 63pp.
Collins, J. T. (1974). *Amphibians and reptiles in Kansas.* Univ. Kansas Mus. Nat. Hist. Pub. Ed. Ser. 1: 1 – 283 pp.
Collins, J. T. (1978). *Rediscovery of the western cottonmouth (Agkistrodon piscivorus leucostoma) in southeastern Kansas.* Trans. Kansas Acad. Sci. 80 (1-2): 71 – 74.
Collins, J. T. (1979). *New records of fishes, amphibians and reptiles.* in Kansas for 1978. Tech. Publ. State Biol. Surv. Kansas 8: 56 - 66.
Collins, J. T. (1982). *Amphibians and reptiles in Kansas.* Second edition. Univ. Kansas Mus. Nat. Hist. Pub. Ed. Ser. 8: 1 – 356 pp.
Conant, R. (1933). *Three generations of cottonmouths, Agkistrodon piscivorus (Lacepede).* Copeia 1933 (l): 43.
Conant, R. (1934). *Two rattlesnakes killed by a cottonmouth.* Science 80 (2078): 382.
Conant, R. (1975). *A field guide to the reptiles and amphibians of eastern and central North America.* Houghton Mifflin Co., Boston, xviii 429 pp.
Cook, F. A. (1962). *Snakes of Mississippi.* Mississippi Game and Fish Comm. Surv. Bull. ii 45pp.
Cope, E. D. (1859). *Catalogue of venomous serpents in the museum of the Academy of Natural Science of Philidelphia, with notes on the families, genera and species.* Proc. Acad. Nat. Sci. Philidelphia 11: 332 - 347.
Cope, E. D. (1875). *Checklist of North American batrachia and reptiles; with a systematic list of the higher groups, and on geographical distribution.* Bull. U.S. Nat. Mus. 1: 1 - 104.
Cope, E. D. (1877). *On some new and little known reptiles and fishes from the Austroriparian region.* Proc. Amer. Philos. Soc. 17 (100): 63 - 68.
Corrington, J. D. (1929). *Herpetology of the Columbia, South Carolina region.* Copeia 1929 (l): 58 - 83.
Davis, D. D.)1936). *Courtship and mating behavior in snakes.* Zool. Series Field Mus. Nat. Hist..20: 257 - 290, figs. 28-34.
Ditmars, R. L. (1907). *The reptile book.* Doubleday, Page and Co. Garden City, New York, xxxii 472 pp.
Ditmars, R. L. (1945). *The reptiles of North America.* Doubleday, Doran and Co. Inc., Garden City, New York, xvi 476pp., 135 pls.

Drda, .W. J. and Kluepfel, D. A. (1979). *Range extension: Agkistrodon piscivorus leucostoma (western cottonmouth).* Herp. Rev. 10 (4): 118.

Dundee, H. A. and Burger, W. L. Jr. (1948). *A denning aggregation of the western cottonmouth.* Nat. Hist. Misc. Chicago Acad. Sci. 21: 1 - 2.

Evans, P. D. (1940). *Notes on Missouri snakes.* Copeia 1940 (l): 53 - 54.

Fitch, H. S. (1960). *Autecology of the copperhead.* Univ. Kansas Publ. Mus. Nat. Hist. 13 (4): 85 - 288, pls. 13-20, 26 figs.

Fogleman, B., Byrd, W. and Hanebrink, E. (1986). *Observations of the male combat dance in the western cottonmouth Agkistrodon piscivorus.* Bull. Chicago Herp. Soc. 21 (1-2): 26 - 28.

Gentry, G. (1956). *An annotated checklist of the amphibians and reptiles of Tennessee.* Journal Tennessee Acad. Sci. 31 (3): 242 - 251.

Githens, T. S. (1931). *Antivenin: its preparation and standardization.* Bull. Antivenin Inst. Amer. 4 (4): 81 - 85.

Githens, T. S. (1935). *Studies on the venoms of North American pit vipers.* Journal Immunology 29: 165 - 173.

Githens, T. S. and Butz, L. W. (1929). *Venoms of North American snakes and their relationship.* Bull. Antivenin Inst. Amer. 2 (4.): 100 - 104.

Gloyd, H. K. (1933). *On the effects of moccasin venom upon a rattlesnake.* Science 78 (2010): 13 - 14.

Gloyd, H. K. (1947). *Notes on the courtship and mating behavior of certain snakes.* Nat. Hist. Misc. Chicago Acad. Sci. 12: 1 - 4.

Gloyd, H. K. (1948). *Another account of the "dance" of the western diamond rattlesnake.* Nat. Hist. Misc. Chicago Acad. Sci. 34: 1 - 3.

Gloyd, H. K. (1969). *Two additional subspecies of North American crotalid snakes, genus Agkistrodon.* Proc. Biol. Soc. Washington 82: 219 - 232.

Gloyd, H. K. and Conant, R. (1943). *A synopsis of the American forms of Agkistrodon (copperheads and : moccasins).* Bull. Chicago Acad. Sci. 7 (2): 147 - 170, 16 figs.

Goodman, J. D. (1958). *Material ingested.by the cottonmouth, Agkistrodon piscivorus at Reelfoot Lake, Tennessee.* Copeia 1958 (2): 149.

Greene, H. W. and Campbell, J. A. (1972). *Notes on the use of caudal lures by arboreal green pit vipers.* Herpetologica 28 (l): 32 - 34.

Hall, H. H. and Smith H.M. (1947). *Selected records of reptiles and amphibians from south eastern Kansas.* Trans. Kansas Acad. Sci . 49 (4): 447 - 454.

Hamilton, W. J. Jr. and Pollack, J. A. (1955). *The flood of some crotalid snakes from Fort.Benning, Georgia.* Nat. Hist. Misc. Chicago Acad. Sci. 140: 1 - 4.

Heatwole, H. and Davidson, E. (1976). *A review of caudal luring in snakes with notes on its occurrence in the Saharan sand viper, Cerastes vipera.* Herpetologica 32 (3): 332 - 336

Henderson, R. W. (1970). *Caudal luring in a juvenile Russell's viper.* Herpetologica 26 (2): 276 - 277.

Henry, G. M. (1925). *Notes on Ancistrodon hypnale, the hump-nosed viper.* Ceylon Journal Sci. Sect. B. (Spolia Zeylanica) 13: 257 - 258.

Hurter, J. (1897). *A contribution to the herpetology of Missouri.* Trans. St. Louis Acad. Sci. 7 (19): 499 - 503.

Hutchinson, R. H. (1929). *On the incidence of.snake-bite poisoning in the United States and the results of the newer methods of treatments.* Bull. Antivenin Inst. Amer. 3 (2): 43 - 57.

Hutchinson, R. H. (1930). *Further notes on the incidence of snakebite poisoning in the United States.* Bull. Antivenin Inst. Amer. 4 (2): 40 - 43.

Jackson, J. F. and Martin, D. L. (1980). *Caudal luring in the dusky pygmy rattlesnake Sistrurus.miliarius barbouri.* Copeia 1980 (4): 926 – 927.

Jobson, H. G. M. (1940). *Reptiles and amphibians from.Georgetown County, South.Carolina.* Herpetologica 2 (l): 39 - 43.

Johnson, L. F., Jacob, J. S. and Torrance, P. (1982) *Annual testicular and androgenic cycles of the cottonmouth (Agkistrodon piscivorus) in Alabama.* Herpetologica 38 (1): 16 - 25.

Kardong, K. V. (1975). *Prey capture in the cottonmouth snake (Agkistrodon piscivorus).* Journal of Herpetology 9 (2): 169 - 175.

Kardong, K. V. (1982). *Comparative study of changes in prey capture behavior of the cottonmouth (Agkistrodon piscivorus) and egyptian cobra (Haja haje).* Copeia 1982 (2): 337 - 343.

Kauffeld, C. F. (1943). *Growth and feeding of newborn Price's and green rock rattlesnakes.* Amer. Midl. Nat. 29: 607 - 614.

Keegan, H. L. and Andrews, T. F. (1942). *Effects of crotalid venom on North American snakes.* Copeia 1942 (4): 251 - 254.

Klauber, L. M. (1956). *Agkistrodon or Ancistrodon.* Copeia, 1956 (4): 258 - 259.

Klimstra, W. D. (1959). *Food habits of the cottonmouth in southern Illinois.* Nat. Hist. Misc., Chicago Acad. Sci. 168: 1 – 8.

Kofron, C. P. (1979). *Reproduction of aquatic snakes in south-central Louisiana.* Herpetologica, 35 (l): 44 - 50.

Lacepede, Compte de (1789). *Histoire naturelle des serpens.* Paris; Hotel de Thou, vol. 2, 527 pp.

Lohoefener, R. and Altig, R. (1983). *Mississippi herpetology.* Bull. Mississippi State Univ. Res. Center 1, vi 66 pp.
Lowe, C. H. Jr. (1942). *Notes on the mating of desert rattlesnakes.* Copeia 1942 (4): 261 - 262.
Lowe, C. H. Jr. (1948). *Territorial behavior in snakes and the so-called courtship dance.* Herpetologica 4 (4): 129 - 135.
Lowe, C. H. and Norris, K. S. (1950). *Aggressive behavior in male sidewinders, Crotalus cerastes, with a discussion of aggressive behavior and territoriality in snakes.* Nat. Hist. Misc., Chicago Acad. Sci. 66: 1 - 13.
Martin, J. and Wood, J. S. (1955). *Notes on the poisonous snakes of the Dismal Swamp area.* Herpetologica, 11(3): 237 - 238.
Martof, B. S. (1956). *Amphibians and reptiles of Georgia.* Univ. Georgia Press, Athens, viii 94pp.
Minton, S. A. (1972). *Amphibians and reptiles of Indiana.* Indiana Acad. Sci Monograph No,3: v 346pp.
Minton, S.A. (1983). *Cottonmouth.* Outdoor Indiana, 48 (September): 14 - 19.
Minton, S. A. and Minton, M. R. (.1980). *Venomous reptiles.* Revised edition. Charles Scribner's Sons. New York, xii 308pp.
Mount, R. H. (1975). *The reptiles and amphibians of Alabama.* Agriculture Experiment Station. Auburn Univ., vii 347pp.
Mount, R. H. and Cecil, J. (1982). *Agkistrodon.piscivorus hybridization.* Herp. Rev. 13(3): 95 - 96.
Munro, D. F. (1947). *Effect of a bite by Sistrurus on Crotalus.* Herpetologica 4 (l): 57.
Necker, W. L. (1939). *Poisonous snakes of Illinois.* Chicago Naturalist 2 (2): 35 - 47.
Neill, W. T. (1947). *Size and habits of the cottonmouth moccasin.* Herpetologica 3 (6): 203 - 205.
Neill, W. T. (1948a). *The yellow tail of juvenile copperheads.* Herpetologica 4 (5): 161.
Neill, W. T. (948b). *Hibernation of amphibians and reptiles in Richmond County, Georgia.* Herpetologica 4 (l): 107 - 114.
Neill, W. T. (1960). *The caudal lure of various juvenile snakes.* Quart. Jour. Florida Acad. Sci. 23 (3): 173 - 200, 2 figs.
Nichol, A. A., Douglas, V. and Peck, L. (1933). *On the immunity of rattlesnakes to their venom.* Copiea (4) : 211 - 213.
Perkins, C. B. (1955). *Longevity of snakes in captivity in the United States as of January 1, 1955.* Copeia (3): 262.
Perry, J. (1977). *KHS members achieve goal -- get cottonmouth.* Kansas Herp. Soc. News. 21: 3 – 4.
Perry, J. (1978). *An observation of "dance" behavior in the western cottonmouth, Agkistrodon piscivorus leucostoma (Reptilia, Serpentes, Vipetidae).* Jour. Herpetology 12 (3): 429 - 431.
Phelps, T. (1984). *Poisonous snakes.* Blandford Press, Poole, Dorset, United Kingdom. viii 237pp., .71 figs.
Pope, C. R. (1978). *The reptile world.* Alfred A. Knopf. New York xxv 325pp.
Ramsey, L. W. (1948). *Combat dance and range extension of Agkistrodon piscivorus leucostoma.* Herpetologica 4 (6): 228.
Raun, G. G. and Gehlbach, F. R. (1972). *Amphibians and reptiles in Texas.* Bull. Dallas Museum Nat. Hist. 2: 1 - 132.
Russell, F. E. (1983). *Snake venom poisoning.* Scholium International, New York, xiv 562pp.
Sanders, R.T. (1951). *Effect of venom injections in rattlesnakes.* Herpetologica 7 (l): 47 - 52.
Schmidt, K. P. (1924). *A list of amphibians and reptiles collected near Charleston, S.C. Copeia 1924 (132):* 67 - 69.
Schmidt, K. P. (1953). *A checklist of North American amphibians and reptiles.* Sixth edition. Amer. Soc. Ichth. Herp. Univ. Chicago Press viii 28 pp.
Secor, S. M. and Carpenter, C. C. (1984). *Distribution maps of Oklahoma reptiles.* Oklahoma Herp. Soc. Spec. Publ. No. 3: 1 - 57.
Shaw, C. E. (1948). *The male combat dance of some crotalid snakes.* Herpetologica 4 (4): 137 - 145.
Shaw, C. E. (1951). *Male combat in American colubrid snakes with remarks on combat in other colubrid.and elapid snakes.* Herpetologica 7 (4): 149 - 168.
Smith, H. M. (1956). *Handbook of amphibians and reptiles of Kansas.* Second edition. Uniy. Kansas Mus. Nat. Hist. Misc. Publ. 9: 1 - 356, 253 figs.
Smith, H. M. and Buechner, H. K. (1947). *The influence of the Balcones Escarpment on the distribution of amphibians and reptiles in Texas.* Bull. Chicago Acad. Sci. 8 (l): 1 - 16.
Smith, P. W. (1961). *The amphibians and reptiles of Illinois.* Illinois Nat. Hist. Survey 28 (l): 1 - 298.
Smith, P. W. and List, J. C. (1955). *Notes on Mississippi amphibians and reptiles.* Amer. Midl. Nat. 53 (l): 115 - 125.
Stebbins, R. C. (1954). *Amphibians and reptiles of Western North America.* McGraw-Hill Book Co., New York. xxii 528pp.

Stejneger, L. H. (1895). *The poisonous snakes of North America.* Smithsonian Inst., UIS. Nat. Mus. 1893: 337 - 487, 19 pls., 70 figs.
Stejneger, L. H. (1907). *Herpetology of Japan and adjacent territory.* Bull. U.S. Nat. Mus. 58: xx 577pp.
Strecker, J. K. (1926). *On the habitats of some southern snakes.* Contrib. Baylor Univ. Mus. (4): 10 - 11.
Sutherland, I. D. (1958). *The "combat dance" of the timber rattlesnake.* Herpetologica 14 (l): 23 - 24.
Swanson, P. L. (1946). *Effects of snake venoms on snakes.* Copeia 1946 (4): 242 - 249.
Tennant, A. (1985). *A field guide to Texas snakes.* Texas Monthly Press, Austin. 260 pp.
Tinkle, D. W. (1959). *Observations of reptiles and amphibians in a Louisiana swamp.* Amer. Midl. Nat. 62 (l): 189 – 205.
Tobey, F. J. (1985). *Virginia's amphibians and reptiles: a distributional survey.* Virginia Herp. Soc. vi 114pp.
Troost, G. (1836). *On a new genus of serpents, and two new species of the genus Heterodon inhabiting Tennessee.* Ann. Lyc. Nat. Hist.. New York 3: 174 – 190.
Webb, R. G. (1970). *Reptiles of Oklahoma.* Univ. Oklahoma Press, Norman, Oklahoma. 370 pp.
Werler, J. E. (1978). *Poisonous snakes of Texas.* Bull. Texas Parks and Wildlife Dept. 31: 53pp.
Wharton, C. H. (1960). *Birth and behavior of a brood of cottonmouths, Agkistrodon piscivorus piscivorus with notes on tail luring.* Herpetologica 16 (2): 125 - 129.
Wharton, C. H. (1966). *Reproduction and growth in the cottonmouths, Agkistrodon piscivorus piscivorus Lacepede, of Cedar Keys, Florida.* Copeia 1966 (2): 149 - 161.
Wharton, C. H. (1969). *The cottonmouth moccasin on Sea Horse Key, Florida.* Bull. Florida State Mus. 14 (3): 227 - 272.
Whisenhunt, M. H. (1949). *An account of copulation of the western diamond rattlesnake.* Nat. Hist. Misc. Chicago Acad. Sci. 49: 1 - 2.
Wilson, A. B. and Minton, S. A. (1983). *Range extension: Agkistrodon piscivorus leucostoma (western cottonmouth).* Herp. Rev. 14 (3): 84.
Wolff, N. O. and Githens, T. S. (1939a). *Record venom extraction from water moccasin.* Copeia 1939 (1): 52.
Wolff, N. O. and Githens, T. S. (1939b). *Yield and toxicity of venom from snakes extracted over a period of two years.* Copeia 1939 (4): 234.
Wood, J. T. (1954). *The distribution of poisonous snakes in Virginia.* Virginia Jour. Sci. 5: 152 - 167.
Wright, A. H. and Wright, A. A. (1957). *Handbook of snakes of the United States and Canada.* Comstock Publishing Assoc., Cornell Univ. Press. 2: ix, 565 - 1106pp.

SUGGESTED READING

Adams, W. H., Jr. (1955). *Water moccasin as a predator on birds.* Wilson Bull. 68 (2): 158.
Allen, E. R. and Neill, W. T. (1950). *The cottonmouth moccasin.* Florida Wildlife 4: 8 - 9, 16.
Blanchard, F. N. (1922). *The amphibians and reptiles of western Tennessee.* Occ. Pap. Mus. Zool., Univ. Michigan 117: 1 - 18.
Battstrom, B. H. (1954). *The fossil pit vipers (Reptilia, Crotalidae) of North America.* Trans. San Diego Soc. Nat. Hist. 12 (3): 31 - 46, 2 f igs.
Broxin, J. H. (1941). *The effects of water moccasin venom on the dog.* Amer. Jour. Physiol. 134: 202 - 207.
Cagle, F. R. (1942). *Herpetological fauna of Jackson and Union Counties, Illinois.* Am. Midl. Nat. 28 (l): 164 - 200.
Carr, A. F. Jr. (1936). *The gu1f-island cottonmouths.* Proc. Florida Acad. Sci. 1: 86 - 90.
Chizar, D., Radcliffe, C. W., Overstreet, R., Poole, T. and Byers, T. (1985). *Duration of strike-induced chemosensory searching in cottonmouths (Agkistrodon piscivorus) and a test of the hypothesis that striking prey creates a specific search image.* Canadian Jour. Zool. 63: 1057 – 1061.
Chizar, D., Scudder, K., Knight, L. and Smith, H. M. (1978). *Exploratory behavior in prairie rattlesnakes (Crotalus viridis) and water moccasins (Agkistrodon piscivorus).* Psychol. Rec. 28: 363 - 368.
Chizar, D., Simonsen, L., Raddliffe, C. W. and Smith, H. M. (1979). *Rate of tongue flicking by cottonmouths (Agkistrodon piscivorus) during prolonged exposure to various food odors and strike-induced chemosensory searching by the cantil (Agkistrodon bilineatus).* Trans. Kansas Acad. Sci. 8 (1): 49 - 54.
Conant, R. (1929). *Notes on a water moccasin in captivity (Agkistrodon piscivorus) (female).* Bull. Antivenin Inst. Amer. 3 (3): 61 - 64.
Conant, R. (1958). *A field guide to reptiles and amphibians.* Houghton Mifflin Co., Boston, 366 pp.

Conant, R. (1977). *The Florida water snake (Reptilia, Serpentes, Colubridae) established at Brownsville, Texas with comments on other herpetological introductions in the area.* Jour. Herpetology 11 (2): 217 - 220.

Corrington, J. D. (1927). *Field notes on some amphibians and reptiles at Biloxi, Mississippi.* Copeia 1927 (165): 98 - 102.

Cottam, C. (1982). *Four good reasons to watch..... your step. A story of poisonous snakes. Texas, Rattlesnakes and cottonmouths.* (Revised from 1960 edition), Texas Game and Fish Mag., 2pp.

Davis, W.D. (1951). *Eastern moles eaten by cottonmouth and gray fox.* Jour. Mammal. 32 (l): 114 - 115.

Dellinger, S. C, and Blacik, J. D. (1938). *Herpetology of Arkansas, part one; the reptiles.* Occ. Pap. Univ. Arkansas Mus. Res. Pap. No. 611: 1 - 47.

Ditmars, R. L. (1941). *Reptiles of the World.* The MacMillan Co., New York. xx 321pp., 89 pls.

Ditmars, R. L. (1957). *Snakes of the World.* The MacMillan Co., New York, xi 207pp., 84 pls.

Dowling, H. G. (19510. *A proposed standard system of counting ventrals in snakes.* British Jour. Herpetology 1 (5): 97 – 98.

Dowling, H. G. (1957). *A review of the amphibians and reptiles of Arkansas.* Occ. Pap. Univ. Arkansas Mus. 3: 1 – 51.

Dunn, E. R. (1918). *A preliminary list of the reptiles and amphibians of Virginia.* Copeia 1918 (53): 1 - 27.

Dunson, W. A. and Freda, J. (1985). *Water permeability of the skin of the amphibious snake, Agkistrodon piscivorus.* Jour. Herpetology 19 (l): 93 - 98.

Ellis, L. (1984). *Cottonmouth research.* Jour. Palm Beach County Herp. Soc. 1 (2). Reprinted from Florida Wildlife, May-June, 1984 2pp.

Ernst, C. H. (1982). *A study of the fangs of snakes belonging to the Agkistrodon* - complex. Jour. Herpetology 16 (1): 472 - 480.

Essex, H. E. (1932). *The physiologic action of the venom of the water moccasin (Agkistrodon.piscivorus).* Bull. Antivenin Inst. Amer. 5 (3): 81.

Fitch, H. S. (1970). *Reproductive cycles in lizards and snakes.* Univ. Kansas Mus. Nat. Hist. Misc. Publ. 52: 247pp.

Force, E. R. (1930). *The amphibians and reptiles of Tulsa County.* Copeia 1930 (2): 25 - 39.

Guidry, E. V. (1953). *Herpetological notes from southeastern Texas.* Herpetologica 9 (1): 49 - 56.

Hickman, C. P. (1922). *An northern record for the water moccasin.* Copeia 1922 (106): 39.

Hulme, J. R. (1952). *Observation of a snake bite by a cottonmouth moccasin.* Herpetologica 1952 (2): 51.

Johnson, T. R. (1980). *Snakes of Missouri.* Missouri Dept. Conservation, 12pp.

Jones, J. M. (1976). *Variations of venom proteins in Agkistrodon snakes from North America.* Copeia 1976 (3): 558 - 562.

Kardong, K. V. (1977). *Kinesis of the jaw apparatus during swallowing in the cottonmouth snake, Agkistrodon piscivorus.* Copeia 1977 (2): 338 - 348.

Kaufman, S. A. and Gibbons, J. W. (1975). *Weight-length relationships in thirteen species of snakes in the southeastern United States.* Herpetologica 31 (1): 31 - 37.

Keiser, E.D. and Wilson, L. D. (1979). *Checklist and key to the amphibians and reptiles of Louisiana.* Second edition. Bull. Lafayette Nat. Hist. Mus. 1: 1 - 49.

Kofron, C. P. (1978). *Foods and habits of aquatic snakes (Reptilia, Serpentes) in a Louisiana swamp.* Jour. Herpetology 12 (4): 543 - 554.

Linzey, D. W. and Clifford, M. J. (1981). *Snakes of Virginia.* Virginia Tech. (VPI), Blacksburg, 159pp.

MacGregor, J. (l986). *Kentucky's venomous snakes.* Kentucky, Happy hunting ground. Dept. Fish and Wildlife Resources 42 (4): 6 - 12.

Martin, D. L. (1984). *An instance of sexual defence in the cottonmouth, Agkistrodon piscivorus.* Copeia 1984 (3): 772 - 774.

Martof, B.S., Palmer, W. M., Bailey, J. R., and Harrison, J. R. III (1980). *Amphibians and reptiles of the Carolinas and Virginia.* Univ. of North Carolina Press, 1-264pp.

Munro, D. F. (1949). *Effect of DDT powder on small cottonmouths.* Herpetologica 5 (3): 71 - 72.

Munro, D. F. (1950). *Additional observations on head bobbing by snakes.* Herpetologica 6 (3): 88.

Myers, G. S. (1924). *Amphibians and reptiles from Wilmington,* N.C. Copeia 1924 (131): 59 – 62.

Neill, W. T. (1949). *Head bobbing a widespread habit of snakes.* Herpetologica 5 (6): 114 - 115.

Palmer, W. M. (1974). *Poisonous snakes of North Carolina.* North Carolina State Mus. Nat. Hist. Raleigh.

Palmer, M. V. (1937). *Some amphibians and reptiles from Reelfoot Lake.* Jour. Tennessee Acad. Sci. 12: 60 - 86.

Penn, G. H. (1943). *Herpetological records from Cameron parish, Louisiana.* Copeia 1943 (1): 58 - 59.

Pope, C. H. (1944). *The poisonous snakes of the New World.* New York Zoological Soc. viii 47pp.

Rahn, H. (1942). *The reproduction cycle of the prairie rattler.* Copeia 1942 (4): 233 - 240.

Rundquist, E. M., Stegall, E., Grow, D. and Gray, P. (1978). *New herpetological records from Kansas.* Trans. Kansas Acad. Sci. 81 (1): 73 - 77.

Schaefer, N. (1976). *The mechanism of venom transfer from the venom duct to the fangs in snakes.* Herpetologica 32 (l): 71 - 76.

Schmidt, K. P. and Davis, D. D. (1941). *Field book of snakes of the United States and Canada.* G.P. Putnam's Sons, New York, xiii 365pp., 19 pls., 103 figs.

Smith, P. W. and Burger, W. L., Jr. (1950). *Additional noteworthy herpetological records for Illinois.* Nat. Hist. Misc. Chicago Acad. Sci. 56: 1 - 3.

Snyder, D. H. (1972). *Amphibians and reptiles of Land Between the Lakes.* Tennessee Valley Authority, 90pp.

Stabler, R. M. (1951). *Some observations on two cottonmouth moccasins made during 12 and 14 years of captivity.* Herpetologica 7 (l): 89 - 92.

Stejneger, L. H. and Barbour, T. (1943). *A checklist of North American amphibians and reptiles.* Fifth edition. Harvard Univ. Press, xix 260 pp.

Trowbridge, A. H. (1937). *Ecological observations on amphibians and reptiles collected in southeastern Oklahoma during the summer of 1934.* Amer. Midl. Nat., 18 (2): 285 - 303.

Yerger, R. W. (1953). *Yellow bullhead preyed upon by cottonmouth moccasin.* Copeia 1953 (2): 115.