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NOTES ON FOOD HABITS OF WINTERING LONG-EARED OWLS IN NORTH-CENTRAL KANSAS

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Abstract- Food habits of Long-eared Owls are well known throughout much of their range, but few data exist for Kansas. A total of 554 pellets were collected from a Long-eared Owl roost at Wilson State Park, Russell County (in 1994 and 1998) to determine prey items. Six-hundred two individual mammals of nine genera were found. Prairie voles, harvest mice, and deer mice represented 79% of these individuals. When combined with data from Geary County, our results showed that the prairie vole was the most abundant prey item, followed by harvest mouse, deer mouse, and the southern bog lemming. This is consistent with data on prey items throughout the Long-eared Owl's range. Assuming a relationship between the mammals taken and their preferred habitats, it appears that Long-eared Owls in north-central Kansas prefer to hunt primarily in dry to mesic prairies with associated, smaller mesic habitats. These habitats are widespread throughout the Smoky Hills, Flint Hills, and Glaciated physiographic regions of northern Kansas. Absence or abundance of Long-eared Owls in a given year may not be indicative of a positive or negative trend in the population, but merely a reflection of fluctuations in small mammal populations.

INTRODUCTION

The food habits of the Long-eared Owl (*Asio otus*) are well documented and consist mostly of small mammals (Bent 1937, Mendall 1944, Marti 1976, Marks 1984, Thompson and Ely 1989, Marks et al. 1994, , Scott 1997). Prey species abundance can change seasonally and annually, therefore affecting food habits of Long-eared Owls (Cable and Bond 1991). The objective of the present study was to report on the food habits of wintering Long-eared Owls in Wilson State Park, (Russell County) in north central Kansas. There have been only a few studies done in Kansas and most have been in the northeast (Rainey and Robinson 1954, Cable and Bond 1991, Fitch et.al. 2003,). Some investigators have suggested that a study of owl pellets gives only a partial glimpse of a bird's intake of food, but Scott (1997) rejected that hypothesis. Pellet and photographic studies indicated that Long-eared Owls regurgitate one pellet every 24 hours and that whatever the owls consume during an evening's hunt is revealed 20-28 hours later in a pellet (Scott 1997).

MATERIALS AND METHODS

Wilson State Park occurs in an area of primarily mixed grass prairie with nearby riparian zones and red cedar (*Juniperus virginiana*) shelterbelts. Common grasses include: big bluestem (*Andropogon gerardii*); little bluestem (*Andropogon scoparius*); blue grama (*Bouteloua gracilis*); sideoats grama (*Bouteloua curtipendula*); and buffalo grass (*Buchloe dactyloides*).

As many as 15 Long-eared Owls and 2 Short-eared Owls (*Asio flammeus*) roosted in a shelterbelt near the park's headquarters building (T13S, R11W, NE 1/4, Sec. 23) from December 1993 through February 1994. On 28-29 May 1994, Young, Wilgers, and a group of their students collected 150 pellets from the shelterbelt for later analyses. As many as 40 Long-eared Owls roosted in the area from winter 1997 through early spring 1998 (December to mid March). Rader collected 404 pellets in mid-April of 1998. Some of the 1998 sample contained pellets that appeared to be broken, but we counted them as individual pellets. This skews the data for the number of skulls per pellet, but does not impact analyses of the species composition of the pellets or their frequency of occurrence. All pellets were transferred to Southwestern College in May 1998, where they were analyzed. Prey items from each pellet (mostly mammal skulls, mandibles and bones) were removed, examined, identified, and their abundance tabulated. Because the Long-eared and Short-eared owls are so closely related, no attempt was made to distinguish between their pellets. Although two Short-eared Owls were present in the 1994 sample, possibly skewing our analysis, the overall influence on our results should be negligible due to the low proportion of Short-eared Owls.

Plant names are from the Great Plains Flora Association (1986), and mammal names are those used by Baker et al. (2003).

RESULTS AND DISCUSSION

Except for one unknown passerine bird (feathers and one bone from a single pellet), nine genera of 602 individual mammals made up all the pellet contents (Table 1). The only genera not identified to species were *Reithrodontomys* and *Peromyscus*. The *Peromyscus* could be *P. leucopus* (white-footed mouse), or *P. maniculatus* (deer mouse). Although the deer mouse frequents open grassland habitats and white-footed mouse is most abundant in woodland environments and shelterbelts, both species can occur in brushy areas, roadsides, and along grassland/woodland borders (Van Deusen and Kaufman 1977, Walker 1978, Bee et al. 1981, Jones et al. 1985, Hayslett and Danielson 1994). Both the plains harvest mouse (*Reithrodontomys montanus*) and the western harvest mouse (*R. megalotis*) could occur in the vicinity with *montanus* preferring short grass and rocky, sparsely vegetated outcrops whereas *megalotis* is more common in taller grassland habitats or brushy vegetation along riparian corridors (Bee et al. 1981, Jones et al. 1985).

In the 1994 sample, the prairie vole (*Microtus ochrogaster*) was the most abundant prey item, followed by harvest mouse, deer mouse, and the southern bog lemming (*Synaptomys cooperi*). These four taxa constituted 94% of the mammals found in pellets (Table 1). In the 1998 sample, harvest mouse was the most abundant prey, followed by prairie vole, deer mouse, and hispid cotton rat (*Sigmodon hispidus*), accounting for almost 90% of the sample (Table 1). The prairie vole, harvest mouse, and deer mouse were the most abundant small mammals in both samples, representing 79% of the 602 individuals found in pellets. The average number of skulls found per pellet was 1.09 (1.91 in 1994 and 0.78 in 1998).

Cable and Bond (1991) found that prairie voles and southern bog lemmings made up 67% of the total prey items in pellets from Geary County, with the white-footed mouse, western harvest mouse, and Ellliot's short-tailed shrew (*Blarina hylophaga*) making up the remainder (Table 1). The average number of skulls per pellet was 1.40 (Cable and Bond 1991). When their data was pooled with ours, the prairie vole was the most common prey species for Long-eared Owls in north-central Kansas, accounting for 33% of the prey items (Table 1). The next most abundant were harvest mice (26%), deer mice (18%), and southern bog lemmings (11%).

Table 1. Mammalian species composition of Long-eared Owl pellets collected at Wilson State Park (Russell County) and from Geary County[1], Kansas.

SPECIES	WILSON 1994 (N = 150) # SKULLS (%)	WILSON 1998 (N=404) # SKULLS (%)	COMBINED YEARS (N = 554) TOTAL (%)	GEARY COUNTY (N = 42) # SKULLS (%)	COMBINED TOTAL (N=596) TOTAL	%
Least Shrew						
Cryptotis parva	2 (0.7)	0	2 (0.3)	0	2	0.3
Elliot's Short-tailed Shrew						
Blarina hylophaga	1 (0.4)	2 (0.6)	3 (0.5)	1 (1.7)	4	0.6
Harvest Mouse						
Reithrodontomys spp.	57 (19.9)	109 (34.5)	166 (27.6)	8 (13.5)**	174	26.3
Deer Mouse						
Peromyscus spp.	55 (19.2)	55 (17.4)	110 (18.3)	10 (17.0)*	120	18.1
Prairie Vole						
Microtus ochrogaster	121 (42.3)	75 (23.7)	196 (32.6)	25 (42.4)	221	33.4
Hispid Cotton Rat						
Sigmodon hispidus	5(1.8)	44 (13.9)	49 (8.1)	0	49	7.4
Southern Bog Lemming						
Synaptomys cooperi	36 (12.6)	19 (6.0)	55(9.1)	15 (25.4)	70	10.6
House Mouse						
Mus musculus	0	7 (2.2)	7 (1.2)	0	7	1.1
Northern Grasshopper Mouse						
Onychomys leucogaster	0	5 (1.6)	5(0.8)	0	5	0.8
Unidentified rodent	9 (3.1)	0	9 (1.5)	0	9	1.4
TOTAL	286 (100.0)	316 (100.0)	602 (100.0)	59 (100.0)	661	100.0

**Reithrodontomys megalotis*
***Peromyscus leucopus*
[1]*(Cable and Bond 1991)*

Marti (1976), Marks (1984), and Cable and Bond (1991) all reported that small mammals make up most of the diet of Long-eared Owls, with voles the most common prey. In continental Europe, small mammals also constitute a majority of the diet of Long-eared Owls (Scott 1997).

Prairie voles, harvest mice, and deer mice represent a large portion of the Long-eared Owl diet, likely due to their occurrences in similar habitats, dry to mesic prairies (Bee et al. 1981, Jones et al. 1985). Mesic habitat, associated with roadside ditches and wetland edges, are favorite habitats for the southern bog lemming (Welker and Choate 1994) and hispid cotton rat, although they can be found in both drier upland prairie and wetland situations. Assuming a relationship between the mammals taken and their preferred habitats, it appears that Long-eared Owls in north-central Kansas prefer to hunt primarily in dry to mesic prairies with associated, smaller mesic habitats. These grasslands can be found throughout the Smoky Hills, Flint Hills, and Glaciated physiographic regions of northern Kansas. Alternatively, the owls may hunt in available grasslands in proportion to their frequency.

The Long-eared Owl is a local winter resident in the state, frequently forming communal roosts of a few individuals to more than 50, often in red cedar shelterbelts associated with a variety of grasslands. Small mammal communities in grasslands can undergo changes seasonally, annually, or even during different decades and centuries (Frey 1992). Additional studies might focus on determining food habits of Long-eared Owls as small mammal communities change with time (Fitch et al. 2003). Lack of Long-eared Owls in a given year, or abundance thereof, may not be indicative of a positive or negative trend in their population but merely a reflection of fluctuations in small mammal populations. This would be important when reviewing population status for a species like the Long-eared Owl, which has a more limited diet of nocturnal mammals, as compared with other sympatric hawks and owls (Marti 1976, Marks 1984, Cable and Bond 1991).

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LITERATURE CITED

Baker, R. J., L. C. Bradley, R. D. Bradley, J. W. Dragoo, M. D. Enstrom, R. S. Hoffman, C. A. Jones, F. Reid, and C. Jones. 2003. Revised Checklist of North American Mammals North of Mexico, 2003. Occasional Papers Museum of Texas Tech University, 229:1-23.

Bee, J. W., G. E. Glass, R. S. Hoffmann, and R. R. Peterson. 1981. Mammals in Kansas. Univ. Kansas, Mus. Nat. Hist., Publ. Ed. Series 7.

Bent, A. C. 1937. Life Histories of North American birds of prey, Part I. U.S. Nat. Mus. Bull. 170.

Cable T. T., and J. S. Bond. 1991. Food habits of Harlan's Hawk and Long-eared Owls in Kansas. Kansas Ornith. Soc. Bull. 42:25-27.

Fitch, H. S., P. von Achen, and G. L. Pittman. 2003. Probable succession related prey changes of Long-eared Owls in Kansas. Kansas Ornith. Soc. Bull. 54(3):42-43.

Frey, J. K. 1992. Response of a mammalian faunal element to climatic changes. J. Mammalogy 73:43-50.
Great Plains Flora Association. 1986. Flora of the Great Plains. Univ. Press of Kansas, Lawrence, Kansas.
Hayslett, L. A., and B. J. Danielson. 1994. Small mammal diversity and abundances in three central Iowa grassland habitat types. Prairie Nat. 26:37-43.
Jones, J. K. Jr., D. M. Armstrong, and J. R. Choate. 1985. Guide to mammals of the Plains States. Univ. Nebraska Press, Lincoln, Nebraska.
Marks, J. S. 1984. Feeding ecology of breeding Long-eared Owls in southwestern Idaho. Can. J. Zool. 62:1528-1533.
Marks, J. S. and D. L. Evans and D. W. Holt. 1994. Long-eared Owl (*Asio otus*). *In*: The Birds of North America No. 123 (A. Poole and F. Gill eds.) Philadelphia: The Academy of Natural Sciences. Washington D. C.: The American Ornithol. Union.
Marti, C. D. 1976. A review of prey selection by the Long-eared Owl. Condor 78:331-336.
Mendall, H. L., 1944. Food of hawks and owls in Maine. J. Wildl. Manage. 8:199-208.
Rainey, D. C., and T. S. Robinson. 1954. Food of the Long-eared Owl in Douglas County, Kansas. Trans. Kansas Acad. Sci. 57:206-207.
Scott, D. 1997. The Long-eared Owl. The Hawk and Owl Trust, London.
Thompson M. C., and C. A. Ely. 1989. Birds in Kansas vol. 1. Univ. Kansas Mus. Nat. Hist. Publ. Ed. Series No. 11.
Van Deusen, M., and D. W. Kaufman. 1977. Habitat destruction of *Peromyscus leucopus* with in prairie woods. Trans. Kansas Acad. Sci. 80:151-154.
Walker, J. R. 1978. The mammals (exclusive of bats) of Cheyenne County, Kansas. Trans. Kansas Acad. Sci. 81:185-229.
Welker, T. L., and J. R. Choate. 1994. Ecogeography of southern bog lemming and meadow vole in north-central Kansas. Prairie Nat. 26:283-286.

BEAK DEFORMITY IN A BROWN-HEADED COWBIRD, WITH NOTES ON CAUSES OF BEAK DEFORMITIES IN BIRDS

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At 10:20 hr on 20 June 2004, I removed a male Brown-headed Cowbird (*Molothrus ater*) from a mistnet at the Myersdale Prairie banding station (39.23º N, 96.95 º W) on Ft. Riley KS. This banding station is part of the Institute for Bird Populations' Monitoring Avian Productivity and Survivorship (MAPS) program, a constant-effort mistnetting initiative which aims to assess and monitor the vital rates and population dynamics of North American landbirds (Institute for Bird Populations, 2002). Upon removing the bird from the net, I noticed that his beak was not normal. The upper mandible curved down and across the left side of the lower mandible (Figures 1-3).

Based on plumage characteristics (Pyle 1997), the bird was a second-year male, meaning that he fledged in the summer of 2003. A prominent cloacal protuberance indicated that he was in breeding condition. He weighed 45.8 g; the average weight of male Brown-headed Cowbirds banded from 1993-2004 on Ft. Riley is 45.45 g (n = 40, std. error = 0.751 g, range: 38.4 to 52.9 g). The unflattened wing chord measurement was 105 mm. The average wing chord of male Brown-headed Cowbirds banded from 1993-2004 on Ft. Riley is 107.1 mm (n = 43, std. error = 0.452 mm, range: 98 to 112 mm). All of these parameters indicated that the bird was healthy and capable of feeding, despite having a deformed beak. The bird was banded, released and flew away normally.

Figure 1 – Left lateral view.

Figure 2 – Frontal view of male Brown-headed Cowbird head.

Figure 3 – Right lateral view.

The structure of the beak is important both to the bird (as it is the main foraging tool) and to the birdwatcher (allowing rapid discrimination and classification). Partly because the beak is so obvious and important, beak deformities have been reported for many families and species of birds (Craves 1994). Various classes of beak deformities seem to be more common in some species (e.g. House Sparrows [*Passer domesticus*], European Starling [*Sturnus vulgaris*]) and some families (Icteridae and Mimidae). The frequency of birds with deformed beaks in a population is generally quite low, in the range of 0.05% (Pomeroy 1962). This makes evolutionary sense, since birds with deformed beaks may not be able to forage or preen efficiently (Benkman and Lindholm 1991), and thus would have lower fitness compared to normal-beaked birds in the population. Previous reports of Brown-headed cowbirds with deformed beaks are relatively uncommon. I was able to find only two published reports (Craves 1994, Sharp and Neill 1979) and one unpublished report (D. Ahlers pers. com.) of beak deformities in this species. The factors that influence the frequency of beak deformities in various species or families are not well understood, and obviously it is impossible to determine the cause(s) of the beak deformity in any individual free-living bird.

The beak, composed primarily of a keratin sheath (rhamphotheca), continues to grow throughout the life of a bird. Growth rates vary with the species; for example, replacement of the entire beak of a large parrot takes approximately 6 months (Gartrell et al. 2003). Growth of the rhamphotheca on the two separate structures that comprise a bird's beak (the upper jawbone or maxilla and the lower jawbone or mandible) must be coordinated in order for the beak to develop to the proper length and morphology. Wouterlood (1976) found that the ultimate size and shape of chicken or duck beaks depend upon the mechanical interrelationship of these two structures, mediated through the contact of the tips of the mandible and maxilla. The morphology of the beak will be changed if mandibular-maxillary contact is experimentally disrupted, causing overgrowth of one or both structures. Thus it follows that processes or events which disrupt this mandibular-maxillary contact can also disrupt normal bill development, perhaps leading to crossed-bill morphology as seen in this Brown-headed Cowbird. Indeed some beak deformities in cage birds (e.g. budgerigars) can be cured by trimming the overgrown mandible or maxilla to the appropriate length, which restores normal contact zones and thus normal growth of the beak (Boussarie 2002). Control of the growth rate of the rhamphotheca is not well understood, but contact between the mandible and maxilla was shown to mutually inhibit growth of the rhamphotheca (Wouterlood 1975). Finally, progress has been made recently in understanding the role of various hormones such as Bone Morphogenetic Protein 4 (BMP4) in controlling beak morphology (Abzhanov et al. 2004, Wu et al. 2004).

A review of available literature indicates three possible causes of beak deformities that have been most commonly proposed. These are: 1) exposure to toxic chemicals in the environment, 2) mutation, and 3) injury. Although it is not possible to assess the specific cause of the beak deformity in this individual cowbird, it is interesting to speculate briefly on these possible etiologies.

Exposure to toxic chemicals has been shown to cause beak deformities in several species of birds. Deformed beaks are more common in populations of birds exposed to known teratogens such as polychlorinated biphenyls (PCBs) and DDT metabolites such as DDE. Fish-eating colonial waterbirds and raptors in the Great Lakes region are known to be exposed to high levels of PCBs and other contaminants (Custer et al. 1999, Fernie et al. 2003, Gilbertson et al. 1991, Kuiken et al. 1999, Ludwig et al. 1995, Ludwig et al. 1996, Ryckman et al. 1998). Hatchlings of some of these species (e.g. Double-crested Cormorant *Phalacrocorax auritus* and Bald Eagle *Haliætus leucocephalus*) exhibit multiple symptoms including beak deformities (Gilbertson et al. 1991). The linkage between these developmental effects and PCB exposure is strengthened by the results of experiments in other species such as American Kestrel (*Falco sparverius*); exposure of parental birds to PCBs significantly increased the frequency of developmental abnormalities, including beak deformities, in embryos (Fernie et al. 2003).

Since the beak continues to grow and renew itself throughout the lifetime of a bird, it is of some interest to know if exposure to known teratogens can also cause defects in adult birds. At present this linkage has not been proven, but has been advanced as a possible factor in recent outbreaks of beak deformities in Black-capped Chickadees (*Poecile atricapillus*), American Crows (*Corvus brachyrynchos*), and more than 20 other bird species in southeast Alaska (Handel 2000). Most of the chickadees reported in this outbreak have upper mandibles that are curved down and across the lower mandible, similar to that seen in the cowbird documented in this report. However, analyses of tissues from these birds did not reveal any obvious accumulation of toxic chemicals such as DDT metabolites or PCBs.

The second possible cause of beak deformities, mutation of a critical developmental gene, also has some support in the scientific literature. Changes such as albinism and reduced beak height occurred more commonly in Barn Swallows (*Hirundo rustica*) near the radioactively contaminated Chernobyl reactor, compared to Barn Swallows from regions of the Ukraine that were distant from Chernobyl (Müller and Mousseau 2001). Mutation has also been hypothesized to be a cause of the beak deformities seen in the southeastern Alaskan birds (Handel 2000); this hypothesis remains untested. As noted above, recent reports indicate that manipulation of the expression of a single growth factor (Bmp4) can have profound effects on beak development, indicating that mutations in multiple genes may not be required in order to result in a deformity of the beak. These considerations indicate that small changes in expression of a small number of developmentally active genes could result in significant changes in beak morphology. If the genetic change does not result in a beak shape that does not reduce fitness (e.g. will still allow the bird to forage and preen appropriately), it could be retained in the next generation and perhaps even increase in frequency.

Finally, it is clear that injuries or infections can profoundly influence beak development. Gartrell et al. (2003) reported that a bacterial sinus infection was the cause of a beak deformity in an Antipodes Island Parakeet (*Cyanoramphus unicolor*) chick. Trauma has also been reported as a cause of beak deformities in other caged birds (Flammer and Clubb 1994). Given that normal beak development and growth is dependent upon contact between the tips of the mandible and maxilla, it is obvious that injuries to the tip of either the mandible or maxilla could result in a beak deformity. It is possible that the Brown-headed Cowbird reported here had an injury or infection which disrupted normal contact between the mandible and maxilla, resulting in the crossed-bill appearance.

In summary, beak deformities in Brown-headed Cowbirds appear to be quite rare. Beak deformities in other species appear to be increasing in recent years, and observers should be alert for additional examples in order to determine if these increases are apparent or real. Increased understanding of the possible causes of beak deformities will also aid in elucidation of the cause in any specific instance.

LITERATURE CITED

Abzhanov, A., M. Protas, B. R. Grant, P. R. Grant, and C. J. Tabin. 2004. Bmp4 and morphological variation of beaks in Darwin's finches. Science 305(5689):1462-1465.

Benkman, C. W. and A. K. Lindholm. 1991. The advantages and evolution of a morphological novelty. Nature 349:519-520.

Boussarie D. Anomalies and disorders in beak and feathers. 2002. Proceedings of the Small Animal Veterinary Association 2002 Congress, Granada.

Craves, J. A. 1994. Passerines with deformed bills. North American Bird Bander 19(1):14-18.

Custer, T. W., C. M. Custer, R. K. Hines, S. Gutreuter, K. L. Stromborg , P. D. Allen, and M. J. Melancon. 1999. Organochlorine contaminants and reproductive success of double-crested cormorants from Green Bay, Wisconsin, USA. Environmental Toxicology and Chemistry 18(6):1209-1217.

Fernie, K., G. Bortolotti, and J. Smits. 2003. Reproductive abnormalities, teratogenicity, and developmental problems in American kestrels (*Falco sparverius*) exposed to polychlorinated biphenyls. Journal of Toxicology and Environmental Health-Part A 66(22):2089-2103.

Flammer, K. and S. Clubb. 1994. Neonatology. *In*: Ritchie, B., G. Harrison and L. Harrison, Eds. Avian Medicine: Principles and Applications. Wingers Publishing. Lake Worth, FL.

Gartrell, B. D., M. R. Alley, and T. Kelly. 2003. Bacterial sinusitis as a cause of beak deformity in an Antipodes Island parakeet (*Cyanoramphus unicolor*). New Zealand Veterinary Journal 51(4):196-198.

Gilbertson, M., T. Kubiak, J. Ludwig, and G. Fox. 1991. Great-Lakes Embryo Mortality, Edema, and Deformities Syndrome (Glemeds) in Colonial Fish-Eating Birds - Similarity to Chick-Edema Disease. Journal of Toxicology and Environmental Health 33(4):455-520.

Handel, C. 2000. Deformed Black-capped Chickadees in south-central Alaska. http://www.absc.usgs.gov/research/bpif/chickadees.html.

Institute for Bird Populations. 2002. Monitoring avian productivity and survivorship (MAPS) program. http://www.birdpop.org/maps.htm.

Kuiken, T., G. A. Fox, and K. L. Danesik. 1999. Bill malformations in double-crested cormorants with low exposure to organochlorines. Environmental Toxicology and Chemistry 18(12):2908-2913.

Ludwig, J. P., H. J. Auman, D. V. Weseloh, G. A. Fox, J. P. Giesy, and M. E. Ludwig. 1995. Evaluation of the effects of toxic chemicals in Great Lakes cormorants: Has causality been established? Colonial Waterbirds 18: 60-69.

Ludwig, J. P., H. Kurita-Matsuba, H. J. Auman, M. E. Ludwig, C. L. Summer, J. P. Giesy, D. E. Tillitt, and P. D. Jones. 1996. Deformities, PCBs, and TCDD-equivalents in double-crested cormorants (*Phalacrocorax auritus*) and Caspian terns (*Hydroprogne caspia*) of the Upper Great Lakes 1986-1991: Testing a cause-effect hypothesis. Journal of Great Lakes Research 22(2): 172-197.

Müller, A. P. and T. A. Mousseau. 2001. Albinism and phenotype of barn swallows (*Hirundo rustica*) from Chernobyl. Evolution. 55(10):2097-2104.

Pomeroy, D. E. 1962. Birds with abnormal bills. British Birds 55:49-72.

Pyle, P. 1997. Identification guide to North American birds: Part I: Columbidae to Ploceidae. Bolinas CA: Slate Creek Press.

Ryckman, D. P., D. V. Weseloh, P. Hamr, G. A. Fox, B. Collins, P. J. Ewins, and R. J. Norstrom. 1998. Spatial and temporal trends in organochlorine contamination and bill deformities in double-crested cormorants (*Phalacrocorax auritus*) from the Canadian Great Lakes. Environmental Monitoring and Assessment 53(1):169-195.

Sharp, M. S. and R. L. Neill. 1979. Physical deformities in a population of wintering blackbirds. Condor 81:427-430.

Wouterlood, F. G. 1975. The mutual relations of structures in the growing bill of chick *Gallus domesticus* and duck *Anas platyrhynchos* embryos. Part 1 Normal embryonic growth and growth after excision of the prospective upper or lower bill in terms of external dimensions. Netherlands Journal of Zoology 25(3):353-368.

Wouterlood, F. G. 1976. The mutual relations of structures in the growing bill of chick *Gallus domesticus* and duck *Anas platyrhynchos* embryos. Part 2 Normal growth of duck embryos external dimensions: the size, shape and position of skeletal elements in the heads of chick and duck embryos lacking an upper or lower bill. Netherlands Journal of Zoology 26(2):266-294.

Wu, P., T. X. Jiang, S. Suksaweang, R. B. Widelitz, and C. M. Chuong. 2004. Molecular shaping of the beak. Science. 305(3589):1465-1466.

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