

North American vultures differ in their reliance on olfactory cues: neuroanatomical evidence



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Background

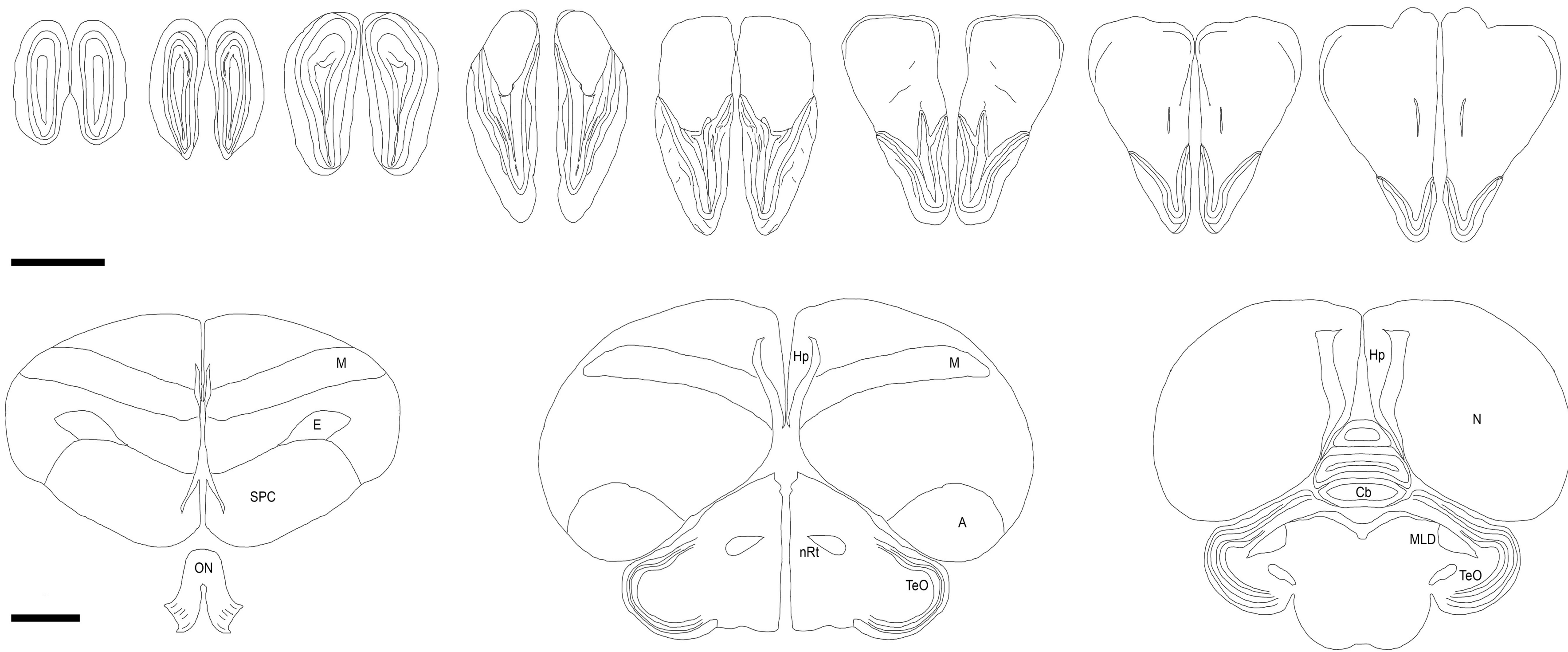
The turkey vulture (*Cathartes aura*) and the black vulture (*Coragyps atratus*) are both carrion feeders with a wide, and largely sympatric distribution across North America. Based on observations and early studies of their foraging behaviour, the two species are thought to differ in reliance on olfactory cues in locating carrion; turkey vultures are thought to predominantly use olfactory cues while black vultures are thought to use visual cues almost exclusively. Behavioural testing in vultures is difficult and an alternative means of determining sensory abilities is to examine the anatomy of sensory structures. Here, we use quantitative neuroanatomy to determine if there are species differences in olfactory and visual regions of the brain that reflect the purported behavioural differences.



Close-up photos of a black vulture (left) and turkey vulture (right). Note that the turkey vulture has much larger nostrils (nares) than the black vulture.

Methods

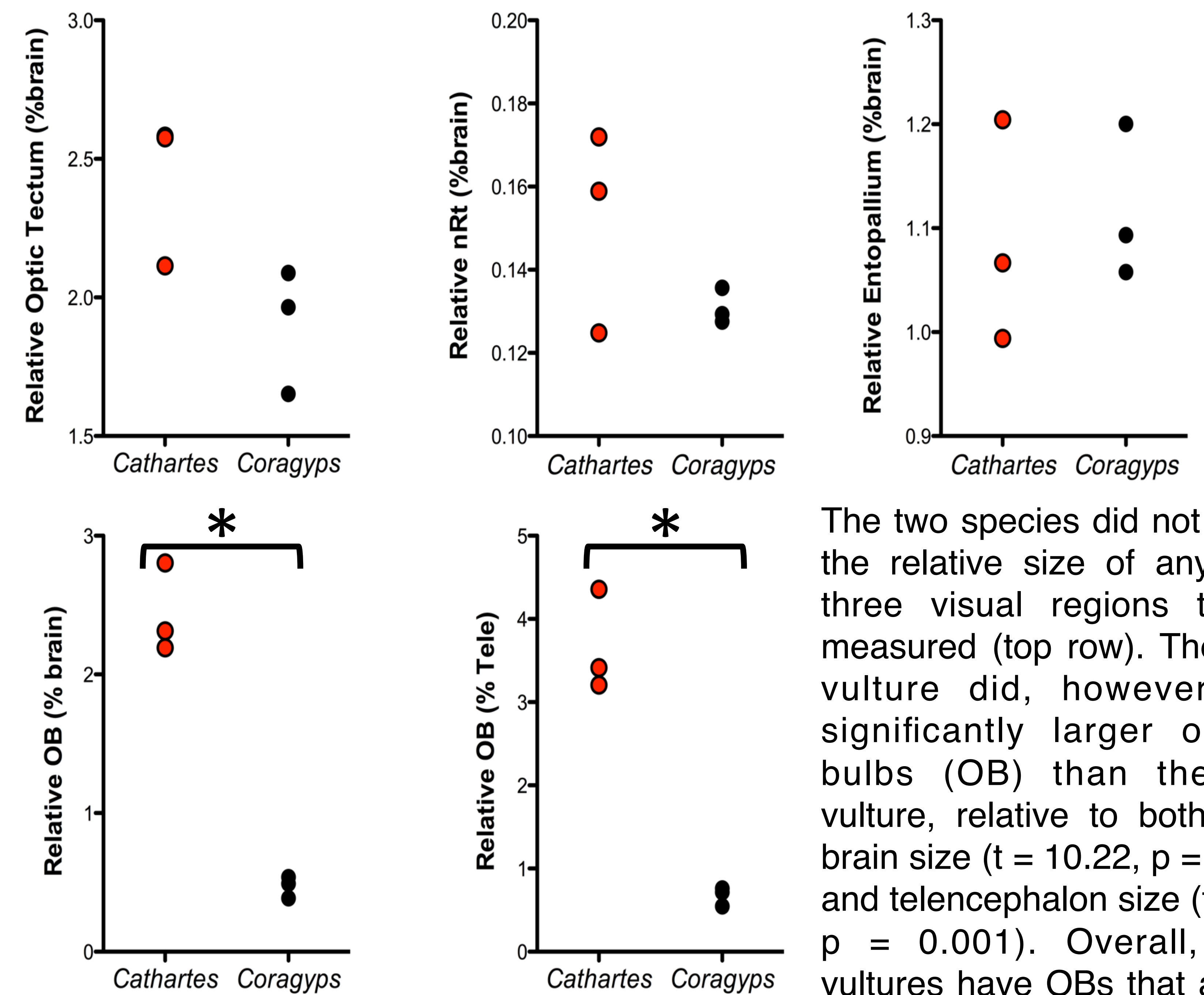
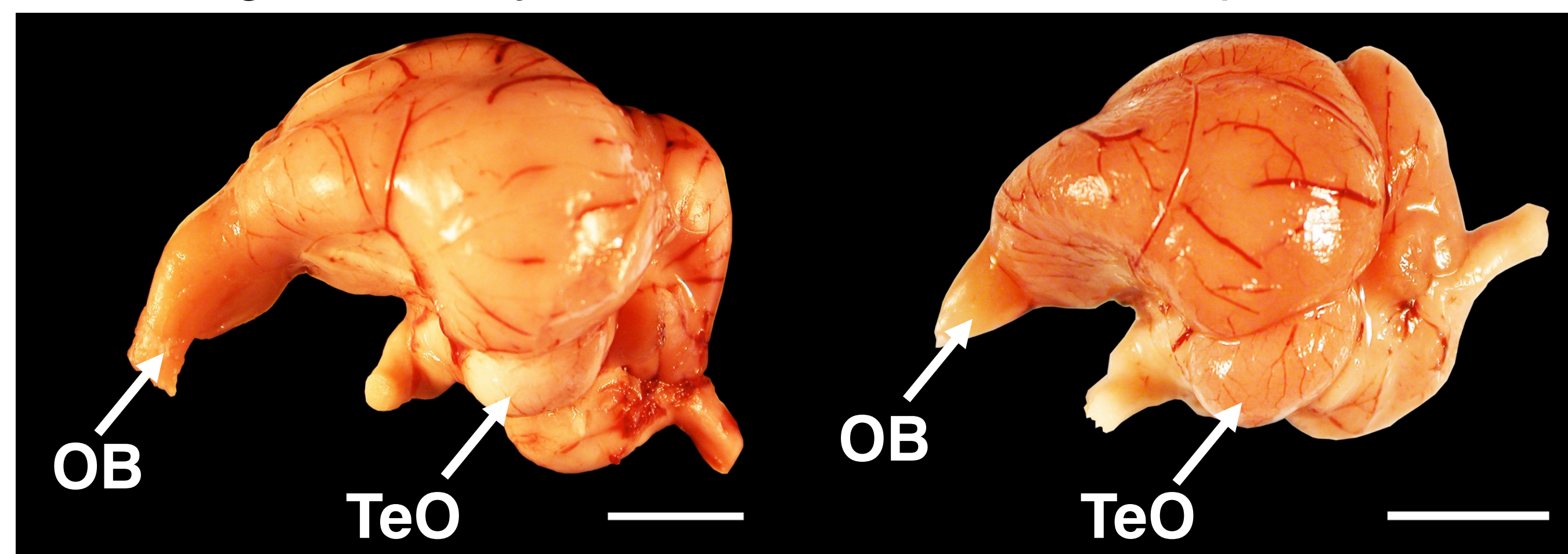
Six specimens (3 of each species) were collected in Tennessee, USA. The heads were immersion fixed in paraformaldehyde and the brains extracted, serially sectioned in the coronal plane and stained for Nissl substance. The volumes of the olfactory bulbs and three visual regions (optic tectum, nucleus rotundus, entopallium) were then measured from virtual slides created with an Olympus VS120 slide scanner. Absolute and relative volumes (% of total brain volume) were then compared with t-tests. We also compared the size of olfactory bulbs with that of over 120 other bird species in our extensive avian brain collection.



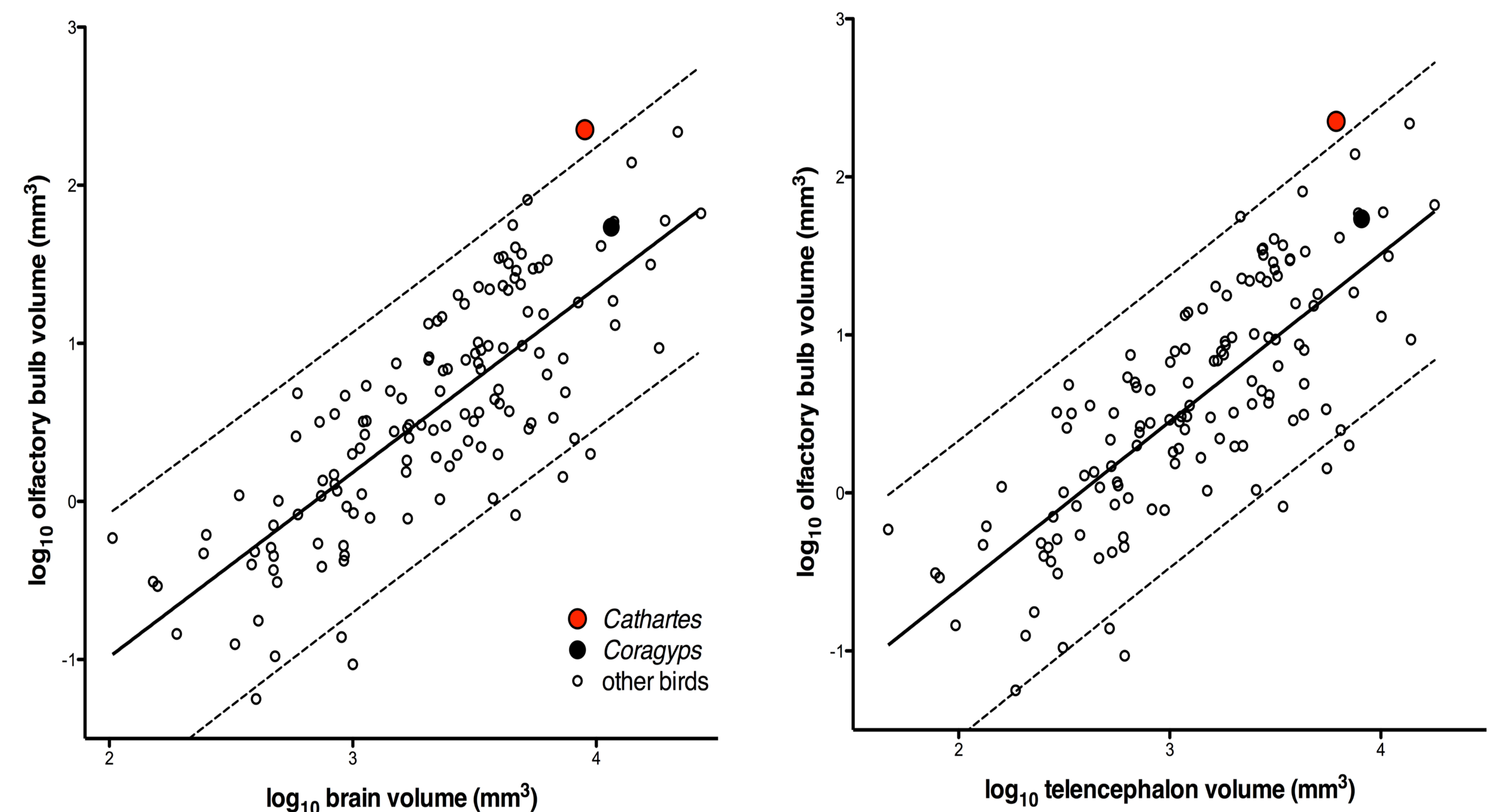
Shown above are line drawings of coronal sections through a turkey vulture brain. The top row shows the layered olfactory bulbs. The bottom row shows several brain regions, including the visual regions measured in this study. Abbreviated brain regions are as follows: A = arcopallium, Cb = cerebellum, Hp = hippocampus, M = mesopallium, MLD = nucleus mesencephalicus lateralis, pars dorsalis, N = nidopallium, nRt = nucleus rotundus, ON = optic nerve, SPC = striatopallidal complex, TeO = optic tectum. Scale bars = 5 mm.

Brain morphology

The overall shape of the brain was markedly different in turkey vultures (left) compared with black vultures (right). Specifically, the turkey vulture appears to have much larger olfactory bulbs (OB) and a smaller optic tectum (TeO) than the black vulture. Turkey vultures did have significantly smaller brains than black vultures ($t = 5.26$, $p = 0.03$). Scale bars = 10 mm.



The two species did not differ in the relative size of any of the three visual regions that we measured (top row). The turkey vulture did, however, have significantly larger olfactory bulbs (OB) than the black vulture, relative to both overall brain size ($t = 10.22$, $p = 0.0005$) and telencephalon size ($t = 8.29$, $p = 0.001$). Overall, turkey vultures have OBs that are 4-5x larger than that of black vultures.



Scatterplots of olfactory bulb volumes against brain size (left) and telencephalon size (right), clearly demonstrate that the turkey vulture has massively enlarged olfactory bulbs. The solid line is the least-squares linear regression line and the dotted lines represent the 95% prediction interval for all 137 species in this data set. Note that the turkey vulture is the only significant outlier and remained so even after incorporating phylogenetic history.

Conclusions and future directions

- The two vulture species do not differ in the relative size of visual regions in the brain.
- Turkey vultures have much larger olfactory bulbs than black vultures, which supports observations on their behaviour.
- Turkey vultures also have the largest olfactory bulbs, relative to brain size, of any extant bird.
- Future studies will focus on quantifying neuron numbers in the olfactory bulbs and examining the brain anatomy of other New World vultures.

Acknowledgements

We wish to thank the staff of the USDA for collecting the vultures, Brian Schmidt and Christina Gebhard for preparing the specimens in the field, the Alexander Wetmore Fund for providing the funding for fieldwork and the following funding agencies:



Canada Foundation for Innovation
Fondation canadienne pour l'innovation