Investigating the Effect of Flock Size on Vigilance in the American Coot (*Fulica americana*) in Relationship to Habitat

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ABSTRACT
Among many anti-predator behaviors, vigilance is observed in many species and plays an important role in survival. In this study, we investigated the effect of flock size on vigilance in American Coots (*Fulica americana*) foraging on land and water, by observing individual birds in these habitats and recording the time spent scanning (i.e., vigilance). Mean flock size was larger on land compared to water and vigilance negatively correlated with flock size. Birds in water were more vigilant compared to on land, regardless of whether they were foraging alone or in flocks. However, the effect of flock size on vigilance showed a weak linear correlation as it was possible that other factors (*e.g.*, human habituation, food kleptoparasitism, or scramble competition) could have also played a role in shaping vigilance. These results suggest that there is a relationship between flock size and vigilance, which are related to previous researches that show a negative correlation between vigilance and flock size.

KEYWORDS
Birds; American Coot; Vigilance; Scanning; Foraging; Flock Size; Habituation; Competition; Behavior

INTRODUCTION

Survival of any organism is essential toward reproduction and the passing of genes to the next generation. In nature, perceived predation risk is a major selective force shaping animal behavior.[1-3] If an animal perceives there is a predator around, it may alter its behavior by decreasing activity level or increasing vigilance.[3, 4]

To scan their environment, birds frequently interrupt feeding and lift their heads.[5-7] This behavior is called vigilance. It has been suggested that there is a negative relationship between vigilance and group size among gregarious species.[8, 9] A few literature reviews in birds and mammals have documented a group-size effect on vigilance, providing overwhelming support for theoretical predictions.[1, 3, 10]

The influence of group size on vigilance has been intensively studied and three hypotheses have been developed to explain why vigilance levels decline with increasing group size. According to the "many eyes" hypothesis, an increase in group size allows for more efficient surveillance, allowing the group to better detect predators while reducing each individual's vigilance.[7, 11, 12] A larger group size also enjoys the benefits of group dilution by lowering an individual's risk of predation, as per the "dilution effect" hypothesis.[13] The decline in individual vigilance can also be supported by the "scramble competition" hypothesis, which explains that the scarcity of resources promotes intraspecific competition, thus lowering each individual's vigilance.[6, 12, 14, 15]

Apart from the effects of group size, other factors also affect vigilance levels. Studies have shown that the characteristics of immediate habitat can also influence vigilance.[16-18] For example, tall vegetation can serve as a good shelter or refuge by lowering detection and decreasing vulnerability to predators, causing animals to lower their vigilance effort.[17, 19, 20] In American Coot, it has been suggested that birds in water probably experience more safety and as such, we hypothesize that birds foraging on water will be less vigilant that birds on land.[21]

We examined vigilance in the American Coots (*Fulica americana*), a highly gregarious species found across North America. The species is known to forages both on land and in water, where their diet consists mainly of aquatic and terrestrial vegetation and insects. The objectives of this study were: (1) to investigate the effect of flock size effect on vigilance, and (2) to compare how the effect varies between terrestrial and aquatic habitats. We hypothesized that vigilance would decrease with flock size (due to the many eyes, dilution, and scramble competition effects), and that birds foraging on land would be significantly more vigilant than in water, as they face a broader array of predators.

METHODS AND PROCEDURES

Study site

The study was conducted between early September and mid-October, 2019 in Apollo Community Regional Park, Lancaster, CA, before fall migration. The park contains three interconnected, human-made lakes with pavement across the outer edge of the lakes. Along with American Coots, the park is also occupied by other avian species such as Canada Goose (*Branta canadensis*), Blue-winged Teal (*Spatula discors*), Eurasian Collared Dove (*Streptopelia decaocto*), and Great Horned Owl (*Bubo virginianus*). Being a recreational park, human presence was high, most prominently around noon. The observations were conducted between 7:00 a.m. – 10:00 a.m. in order to minimize the effect of human disturbance.

Field work and data collection

Observations were made on flock sizes of two or more individuals as well as lone foragers. In order to avoid disturbing the subjects, the observations were made from a pavement at least 15-20 meters away from the coots. For the purpose of the study, vigilance was identified as an individual raising its head (scan) and non-vigilance included behaviors such as pecking the water or ground, preening, walking, or diving. Individual birds were observed using the focal sampling method.[22] Each observation lasted one minute, during which the time spent scanning (vigilance) was recorded with a stopwatch. During a session, one person reported the observation while another person operated a stopwatch, and recorded the data. Each time the bird switched behavior from vigilance to non-vigilance and vice versa, a lap was taken on the watch. After the one-minute observation, the vigilance laps were added up to determine the total time spent vigilant. In order to keep the flock size the same during each session, the observation was ceased (and not used in analysis) when the flock size changed, the bird went out of sight, or was disturbed by the presence of humans. Data was collected separately for coots foraging in water and on land.

Data analysis

A total of 630 coots were observed with 324 individuals foraging on land and 306 individuals in water. To prevent pseudoreplication, since the observations were conducted as part of a course-based research project by different individuals at different times, 149 data points from each habitat were randomly selected for analysis. Student's t-test was used to determine if mean flock size and mean vigilance time were significantly different between birds on land and water. To analyze the effect of flock size on vigilance, a Pearson's correlation test was performed. Finally, to investigate the effect of habitats (Land vs water) and birds foraging alone or in a flock, on vigilance (dependent variable) ANOVA test was conducted.

RESULTS

On land, the number of birds in a flock ranged from 2 – 21, with 16.1% foraging alone. In water, the number of birds in a flock ranged from 2 – 7, with 19.5% foraging alone. On average, the flock size on land was significantly larger than in water, and birds spent significantly less time scanning (vigilance) on land compared to water (**Table 1**). Regardless of the habitat, birds foraging alone spent significantly more time scanning compared to birds foraging in flocks of two or more ($F_{1, 294} = 22.5$, $p < 0.0001$, **Figure 1**). Furthermore, birds on land scanned significantly less than birds in water ($F_{1, 249} = 146.9$, $p < 0.001$, **Figure 1**). Birds alone in water scanned the most while birds in a flock on land scanned the least (**Figure 1**). There was a weak negative linear relationship between flock size and vigilance on land, ($r = -0.283$, $p = 0.013$, **Figure 2**). There was also a weak negative linear relationship between flock size and vigilance in water, but it was not statistically significant ($r = -0.205$, $p = 0.077$, **Figure 3**).

	Land		Water		d.f.	t	p
	Mean	SD	Mean	SD			
Flock size	5.6	4.6	2.8	1.5	296	6.89	<0.001
Vigilance (sec)	21.3	16.3	41	12.2	296	11.83	< 0.001

Table 1. Mean flock size and vigilance for American Coots on land and in water along with results of an independent t-test comparing means.

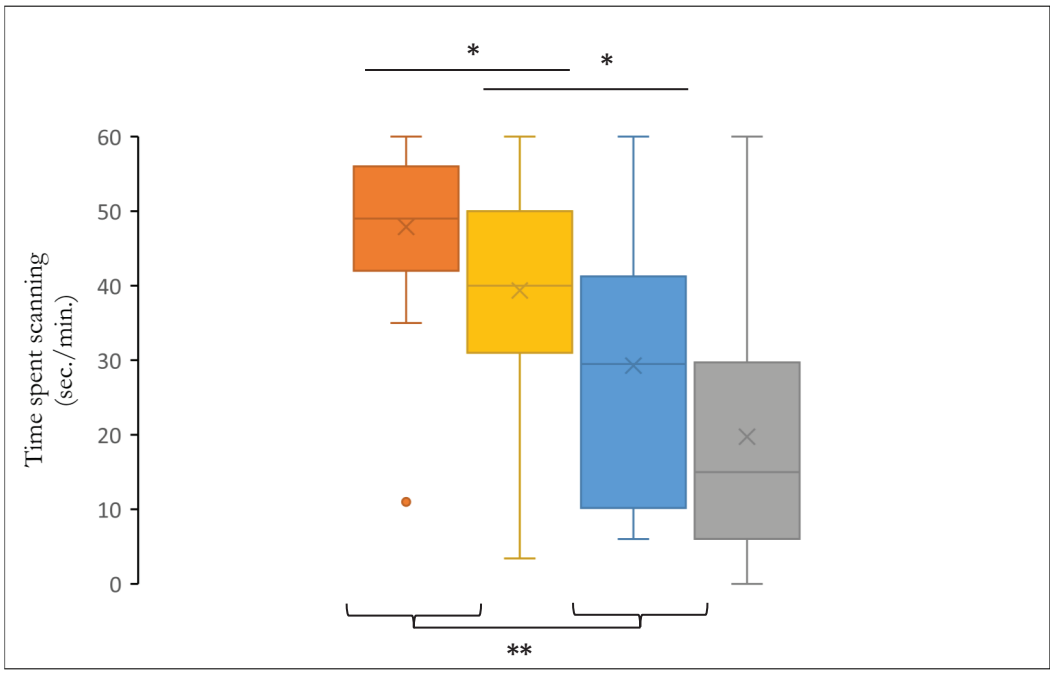

Figure 1. Time birds spent scanning either foraging alone on land (■) or on water (■), and in a flock on land (■) or on water (■). In the box plots, the boundary of the box closest to zero indicates the 25th percentile, a black line within the box marks the median, and the X within the box marks the mean. Whiskers above and below the box indicate the 10th and 90th percentiles. Points above and below the whiskers indicate outliers outside the 10th and 90th percentiles. (* $p < 0.0001$, ** $p < 0.001$)

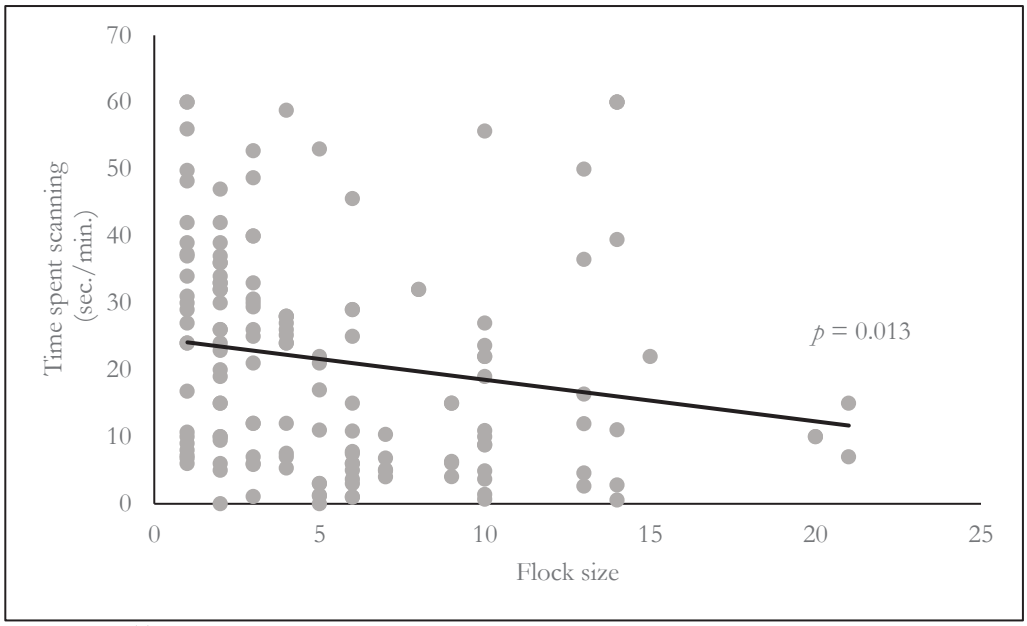

Figure 2. The time spent scanning (vigilant) as a function of flock size of the American Coot on land (N = 149).

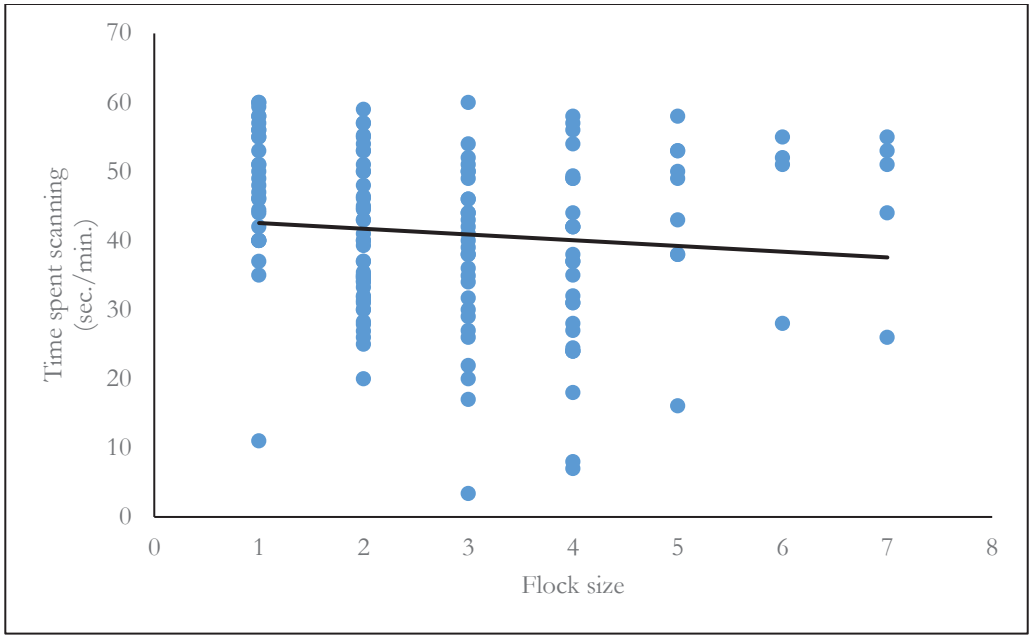

Figure 3. The time spent scanning (vigilant) as a function of flock size of the American Coot in water (N = 149).

DISCUSSION

The decrease in individual vigilance with increasing group size is one of the most commonly reported relationships in the field of animal behavior.[1, 10, 23] Results of this study showed that there was a negative correlation between vigilance and flock size, albeit a weak linear correlation, on land (**Figure 2**) but not water (**Figure 3**), coinciding with prior findings for this genus.[21, 24] In addition, the American Coots in this study foraged in larger flocks and were less vigilant while on land compared to water (**Table 1**).

There are a number of possible explanations to the weak effect of flock size on vigilance in our study. In nature vigilance may serve a number of functions in obtaining information about the environment.[25] Nevertheless, predator detection is a major function in many species. Thus, one would expect vigilance to increase with the risk of predation and this is supported by many observations of increases in vigilance on or after exposure to a predator.[1, 10] Conversely, reduction or absence of predators would minimize the effect of vigilance.[23] This might be a reasonable explanation for the weakness of vigilance in the American Coots studied here. Apollo Regional Park is a low-risk habitat for wildlife with little activity of avian predators (Dr. Callyn Yorke of Antelope Valley College, Personal communication) and since the park is fenced off, there are no mammalian predators. While there were park visitors who brought their pets, mostly dogs (*Canis familiaris*), there were no instances of these animals having predator-prey interactions. Human interactions are often perceived as predatory, which induces fear and physiological changes in animals. This effect has been documented to have significant impact on the foraging efficiency of birds.[21, 26] It is evident that human interactions can cause changes in birds' defense mechanisms, such as vigilance, which directs energy away from foraging in favor of these mechanisms.[27] As such, human interactions tend to negatively affect reproduction and feeding behaviors of birds, though the degree of impact varies among species.[26] In certain cases, individuals exposed to prolonged, non-threatening interaction with humans have shown to decrease their vigilance (*e.g.*, acclimation), but still retain a level of 'fear' toward people.[26] The combination of low predation risk with frequent positive human interaction might have induced habituation to human's presence causing these birds to be relaxed in the presence of humans. Animals that frequently experience nonlethal interactions with humans tend to habituate to humans.[28, 29] This adaptation allows them to optimize their foraging strategy, cutting energy-wasting escape and vigilance behavior toward non-lethal human disturbance and devoting more time to feeding or preening due to an assessment of low-risk surrounding. In such a situation, factors other than predation might influence vigilance. For example, the opportunity to kleptoparasitize food from conspecifics had the greatest influence on vigilance in Northwestern Crows (*Corvus caurinus*, recently lumped with American Crow, *Corvus brachyrhynchos*).[30] While reduced vigilance for predators in larger groups is a logical hypothesis, the presence of larger groups also may mean more food stealing opportunities and food loss risk for foragers. Coots normally bring their food plants to the water surface to eat them there, and this behaviour allows other waterfowl species to kleptoparasitize them. Herbivorous dabbling ducks, such as American Wigeon (*Mareca Americana*) and Gadwall (*M. strepera)*, have frequently been observed kleptoparasitizing coots and do reside in Apollo Park.[31, 32] Thus it is reasonable to speculate that kleptoparasitism may have caused the coots in our study to scan more frequently when in water compared to land.

The presence of more individuals in close proximity, regardless of species, might increase scramble competition, resulting in coots devoting less time to vigilance and more to feeding.[33, 34] In this study, birds foraging alone, regardless of habitat, were significantly more vigilant than birds in flocks (**Figure 1**). This is to be expected given the greater vulnerability of a single individual to predation and has been extensively documented in other studies.[35-37] Furthermore, though food density was not measured in the study area, birds on land tended to be in larger flocks compared to water, thus increasing scramble competition. This could have also minimized the strength of the association between vigilance and flock size.

Finally, American Coots either feed in water (by diving, dabbling, or surface feeding) or on land (by grazing or picking up food from the ground). These two environments might be perceived differently in terms of predation risk. Birds on land might be susceptible to both aerial and terrestrial predators, while birds in water are only exposed to aerial threats. In a previous study, feeding-bout lengths in aquatic habitat were longer than terrestrial feeding in Eurasian Coots.[21] This study suggests that these birds perceived less risk in aquatic habitat and spent more time feeding, thus conversely less time scanning. Though we did not measure feeding bouts, our results contradict (albeit indirectly) these conclusions, as the American coots in this study were more vigilant in water than land whether they were foraging alone or in flocks.

CONCLUSIONS

We found a significant correlation between flock size and vigilance rate. American Coots were less vigilant in larger flocks and exhibited the highest amount of vigilance when foraging alone. In general, this study is in agreement with previously published studies of this genus.[21, 24] However, many other factors might influence vigilance.[10, 23] We believe that habituation to humans,[28, 29] food kleptoparasitism,[30] and possibility of scramble competition[33, 34] weakened the relationship between vigilance and flock size. Future studies should investigate individual variation in vigilance of a specific bird, in order to track its patterns of plasticity as the flock size changes.

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REFERENCES

1. Lima, S.L., and Dill, L.M. (1990) Behavioral decisions made under the risk of predation: a review and prospectus. *Candian Journal of Zoology* 68: 619–640. *https://doi.org/10.1139/z90-092*
2. Lima, S.L. (1998) Nonlethal Effects in the Ecology of Predator-Prey Interactions. *BioScience* 48: 25–34. *https://doi.org/10.2307/1313225*
3. Caro, T. (2005) Antipredator Defenses in Birds and Mammals. University of Chicago Press, Chicago, IL 592 pages.
4. Kats, L.B., and Dill, L.M. (1998) The scent of death: Chemosensory assessment of predation risk by prey animals. *Écoscience* vol. 5, no. 3, 1998, p. 361-394. *https://doi.org/10.1080/11956860.1998.11682468*
5. Bednekoff, P. and Lima, S.L. (2002) Why Are Scanning Patterns So Variable? An Overlooked Question in the Study of Anti-Predator Vigilance. *Journal of Avian Biology* 33(2): 143-149. *https://doi.org/10.1034/j.1600-048X.2002.330204.x*
6. Beauchamp, G. (2003) Group-size effects on vigilance: a search for mechanisms. *Behavioural processes* 63: 141-145. *https://doi.org/10.1016/S0376-6357(03)00011-1*.
7. Randler, C. (2005) Vigilance during Preening in Coots Fulicia atra. *Ethology* 111: 169—178. *https://doi.org/10.1111/j.1439-0310.2004.01050.x*
8. Zhang, Y., Luo, Z., & Liu, B. (2014) The effect of group size on the vigilance of Mongolian gazelle (Procapra gutturosa). *Folia Zoologica* 63(2): 81-86. *https://doi.org/10.25225/fozo.v63.i2.a5.2014*
9. Dalerum, F., Lange, H., Skarpe, C., Rooke, T., Inga, B. and Bateman, P. W. (2008) Foraging competition, vigilance and group size in two species of gregarious antelope. *South African Journal of Wildlife Research* 38(2): 138–145. *https://doi.org/10.3957/0379-4369-38.2.138*
10. Elgar, M.A. (1989) Predator vigilance and group size in mammals and birds: a critical review of the empirical evidence. *Biological Reviews* 64: 13–33. *https://doi.org/10.1111/j.1469-185X.1989.tb00636.x*
11. Pulliam, H.R. (1973). On the advantages of flocking. *Journal of theoretical biology* 38(2): 419-422. *https://doi.org/10.1016/0022-5193(73)90184-7*.
12. Boukhriss, J., Selmi, S., Béchet, A., and Nouira, S. (2007) Vigilance in Greater Flamingos Wintering in Southern Tunisia: Age-Dependent Flock Size Effect. *Ethology* 113: 377 - 385. *https://doi.org/10.1111/j.1439-0310.2007.01335.x*

13. Hamilton, W.D. (1971) Geometry for the selfish herd. *Journal of theoretical biology* 31(2): 295-311. *https://doi.org/10.1016/0022-5193(71)90189-5*

14. Beauchamp, G. (2001) Should vigilance always decrease with group size? *Behavioral Ecology and Sociobiology* 51: 47-52. *https://doi.org/10.1007/s002650100413*

15. Rieucau, G., and Giraldeau, L.A. (2009). Group size effect caused by food competition in nutmeg mannikins (Lonchura punctulata). *Behavioral Ecology* 20: 421-425. https://doi.org/10.1093/beheco/arn144

16. Metcalfe NB. (1984) The effects of habitat on the vigilance of shorebirds: Is visibility important? Animal Behaviour. 1984;32:981–985. *doi: 10.1016/S0003-3472(84)80210-9*.

17. Lima SL. (1987) Distance to Cover, Visual obstructions, and vigilance in house sparrows. Behaviour. 1987;102:231–238. *doi: 10.1163/156853986X00144*.

18. Lazarus J, Symonds M. (1992) Contrasting effects of protective and obstructive cover on avian vigilance. Animal Behaviour. 1992;43:519–521. *doi: 10.1016/S0003-3472(05)80110-1*.

19. Moreno S, Delibes M, Villafuerte R. (1996) Cover is safe during the day but dangerous at night: the use of vegetation by European wild rabbits. Canadian Journal of Zoology. 1996;74:1656–1660. *doi: 10.1139/z96-183*.

20. Tchabovsky VA, Krasnov B, Khokhlova SI, Shenbrot IG. (2001) The effect of vegetation cover on vigilance and foraging tactics in the fat sand rat *Psammomys obesus*. Journal of Ethology. 2001;19:105–113. *doi: 10.1007/s101640170006*.

21. Randler, C. (2006). Feeding Bout Lengths Differ between Terrestrial and Aquatic Feeding Coots Fulica atra. *Waterbirds: The International Journal of Waterbird Biology* 29(1): 95-99. *https://doi.org/10.1675/1524-4695(2006)29[95:FBLDBT]2.0.CO;2*

22. Altmann, J. (1974). Observational Study of Behavior: Sampling Methods. *Behaviour* 49(3/4): 227-267. *https://doi.org/10.1163/156853974X00534*

23. Roberts, G. (1996). Why individual vigilance declines as group size increases. *Animal Behaviour* 51: 1077-1086. *https://doi.org/10.1006/anbe.1996.0109*

24. Severcan, Ç., & Yamaç, E. (2011). The effects of flock size and human presence on vigilance and feeding behavior in the Eurasian Coot (Fulica atra L.) during breeding season. *Acta Ethologica* 14(1): 51–56. *https://doi.org/10.1007/s10211-010-0089-y*

25. Lima, S. (1990) Evolutionarily stable antipredator behavior among isolated foragers: On the consequences of successful escape. *Journal of Theoretical Biology* 143: 77-89. *https://doi.org/10.1016/S0022-5193(05)80289-9*

26. Price, Megan. (2008) The impact of human disturbance on birds: A selective review, in *Too close for comfort (Munn, A., Lunney, D., and Meikle, W., Eds.)*, 163-196, Royal Zoological Society of New South Wales, Mosmon, Australia. *https://doi.org/10.7882/FS.2008.023*.

27. Siegel, H. S. (1980). Physiological stress in birds. *Bioscience* 30: 529–534. *https://doi.org/10.2307/1307973*

28. Louis, S. & Berre, M. (2000). Adjustment of flight distances in Marmota marmota. *Canadian Journal of Zoology* 78: 556-563. *https://doi.org/10.1139/z99-242*

29. Stankowich, T. (2008). Ungulate flight responses to human disturbance: A review and meta-analysis. *Biological Conservation* 141: 2159-2173. *https://doi.org/10.1016/j.biocon.2008.06.026*

30. Robinette, R.L., & Ha, J.C. (2001). Social and ecological factors influencing vigilance by northwestern crows, Corvus caurinus. *Animal Behaviour* 62: 447-452. *https://doi.org/10.1006/anbe.2001.1772*

31. Amat, J., & Soriguer, R. (1984). Kleptoparasitism of Coots by Gadwalls. *Ornis Scandinavica (Scandinavian Journal of Ornithology)*, 15(3), 188-194. *doi:10.2307/3675962*

32. Eddleman, W.R., Patterson C.T., & Knopf, F.L. (1985) Interspecific relationships between American coots and waterfowl during fall migration. The Wilson Bulletin, 97(4), 463-472

33. Beauchamp, G. (2007). Competition in foraging flocks of migrating semipalmated sandpipers. *Oecologia* 154: 403-409. *https://doi.org/10.1007/s00442-007-0818-8*

34. Beauchamp, G. (2012). Foraging speed in staging flocks of semipalmated sandpipers: evidence for scramble competition. *Oecologia* 169(4): 975–980. *https://doi.org/10.1007/s00442-012-2269-0*

35. Ortiz, C. A., Pendleton, E. L., Newcomb, K. L., & Smith, J. E. (2019). Conspecific presence and microhabitat features influence foraging decisions across ontogeny in a facultatively social mammal. *Behavioral Ecology & Sociobiology*, 73(4), N.PAG. *https://doi.org/10.1007/s00265-019-2651-6*

36. Ridley, A. R., Raihani, N. J., & Nelson-Flower, M. J. (2008). The cost of being alone: the fate of floaters in a population of cooperatively breeding pied babblers Turdoides bicolor. *Journal of Avian Biology*, 39(4), 389–392. *https://doi.org/10.1111/j.0908-8857.2008.04479.x*

37. Pettorelli, N., Coulson, T., Durant, S.M., & Gaillard, J.M. (2011) Predation, individual variability and vertebrate population dynamics. *Oecologia 167*, 167(2):305-14. *https://doi.org/10.1007/s00442-011-2069-y*

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Roxanne Cota partook in this research as a 3rd year community college student at Antelope Valley College. She now attends UC Riverside and is pursuing a B.S. in Biological Sciences. Her future education plans include completing a physician assistant master's degree program.

Miguel Sicaja is an undergraduate seeking to obtain a major in Marine Biology. He completed half of his education at Antelope Valley College and will attend UC Santa Barbara for Fall 2020. His major at UC Santa Barbara is Aquatic Biology, in which he hopes to complete his undergraduate education and gain experience in working with aquatic life. After obtaining a bachelor's degree, he will aim to gain a master's degree to further his goals for shark conservation.

Gabriel Cox completed this manuscript as a sophomore at Antelope Valley College, Lancaster, California. He will graduate with an Associate of Science degree in biology and chemistry in the spring of 2021. His future plans are to obtain a graduate degree in molecular biology.

Brandon Wakefield was a sophomore at Antelope Valley College when this research paper was completed. He is currently transferring to University of California, San Diego and will earn a B.A. in Microbiology in the spring of 2022. During his enrollment in UCSD, he plans on exploring the range of occupational opportunities in the field of Microbiology.

PRESS SUMMARY

Many studies about animal's vigilance have shown a negative correlation between flock size and scanning rate among gregarious species. This study investigated the effect of flock size on vigilance in *Fulica americana* foraging on land and water, adding to the extensive data of anti-predatory behavior among animals. Data was collected by recording the coots scanning rate within their respective habitats. The results show that birds in water were more vigilant compared to the ones on land regardless if they were foraging alone or in flocks. While *Fulica Americana* exhibits a negative correlation between flock size and vigilance for both habitats, the effect of flock size on vigilance was minimal as it was possible that other factors (human habituation, food kleptoparasitism, or scramble competition) could have also played a role in shaping vigilance.