

Vulture Vision: Low Visibility Vision and High-Speed Visual Capabilities of Black and Turkey Vultures

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2026 Aviation Wildlife Management Conference



Bird Strikes & Vultures in U.S.

Black Vulture

- >80% of off-airport collisions cause damage¹



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Turkey Vulture

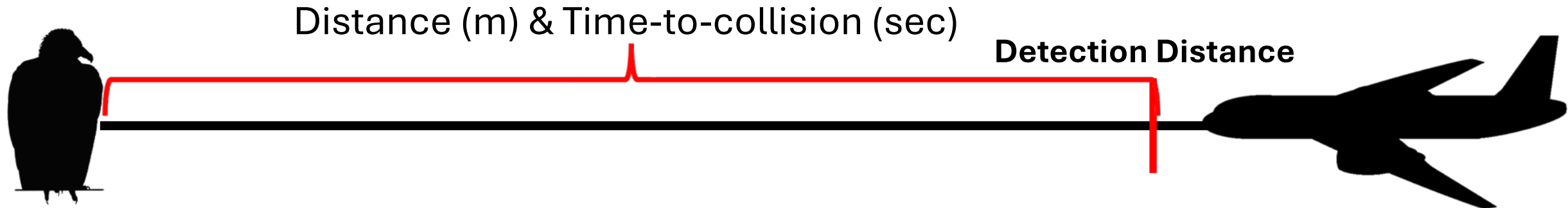
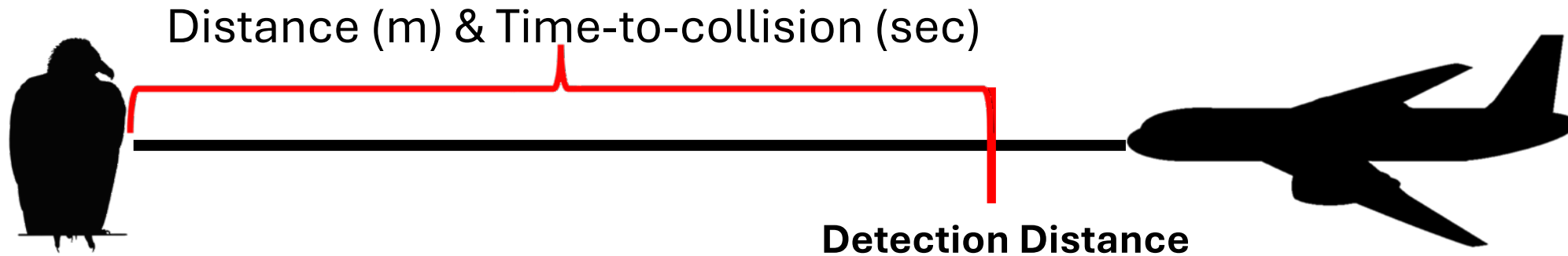
- >75% of off-airport collisions cause damage¹



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Avian Vision

- Longer detection distances allow for more time and space for the bird to escape.



Tuning Onboard Lighting to Vulture Eyes

What do we need to know to make a difference in collision mitigation?

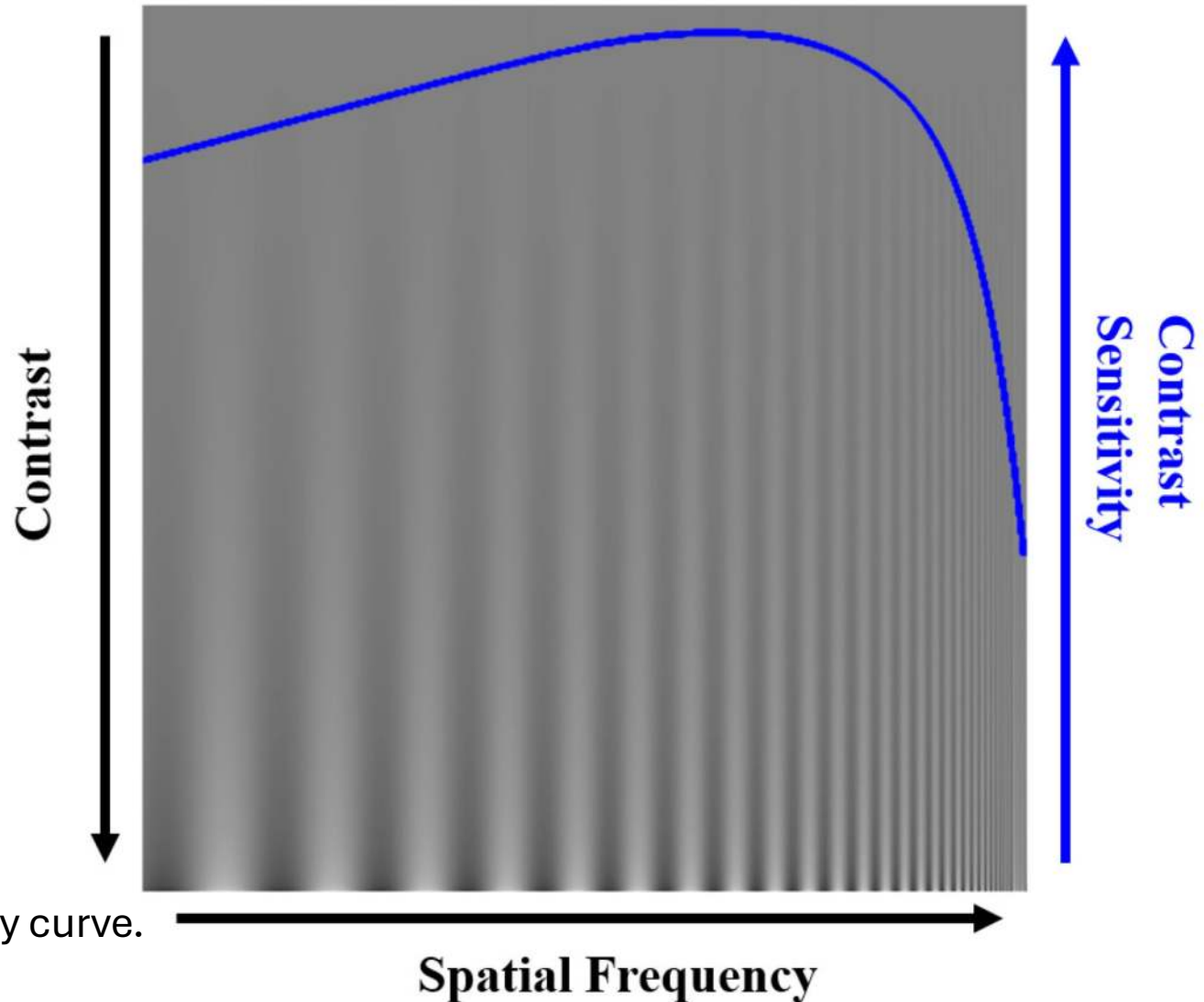
1. Blind spots (visual fields)
2. Maximum detection distances (visual acuity)
3. Is aircraft detectable against visual background?
(**contrast**/wavelength sensitivity)
4. Maximum allowable time-to-collision (**temporal resolution**)

I. Contrast Sensitivity

Distinguishing Objects Against the Background

Achromatic Contrast Sensitivity

- What size of object can be resolved from a given visual background?

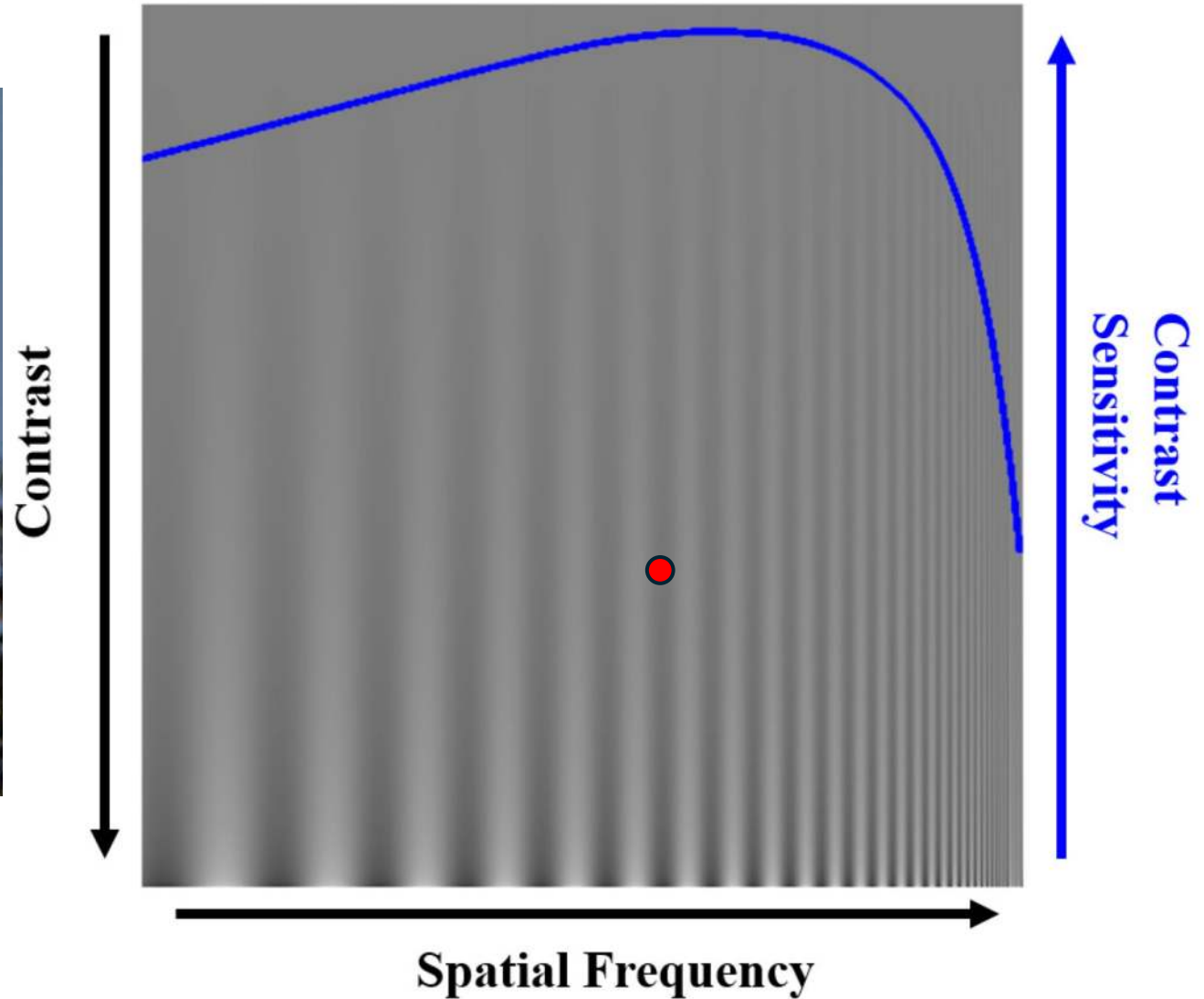


Example of a contrast sensitivity curve.
Image from Qian et al. 2023

Achromatic Contrast Sensitivity



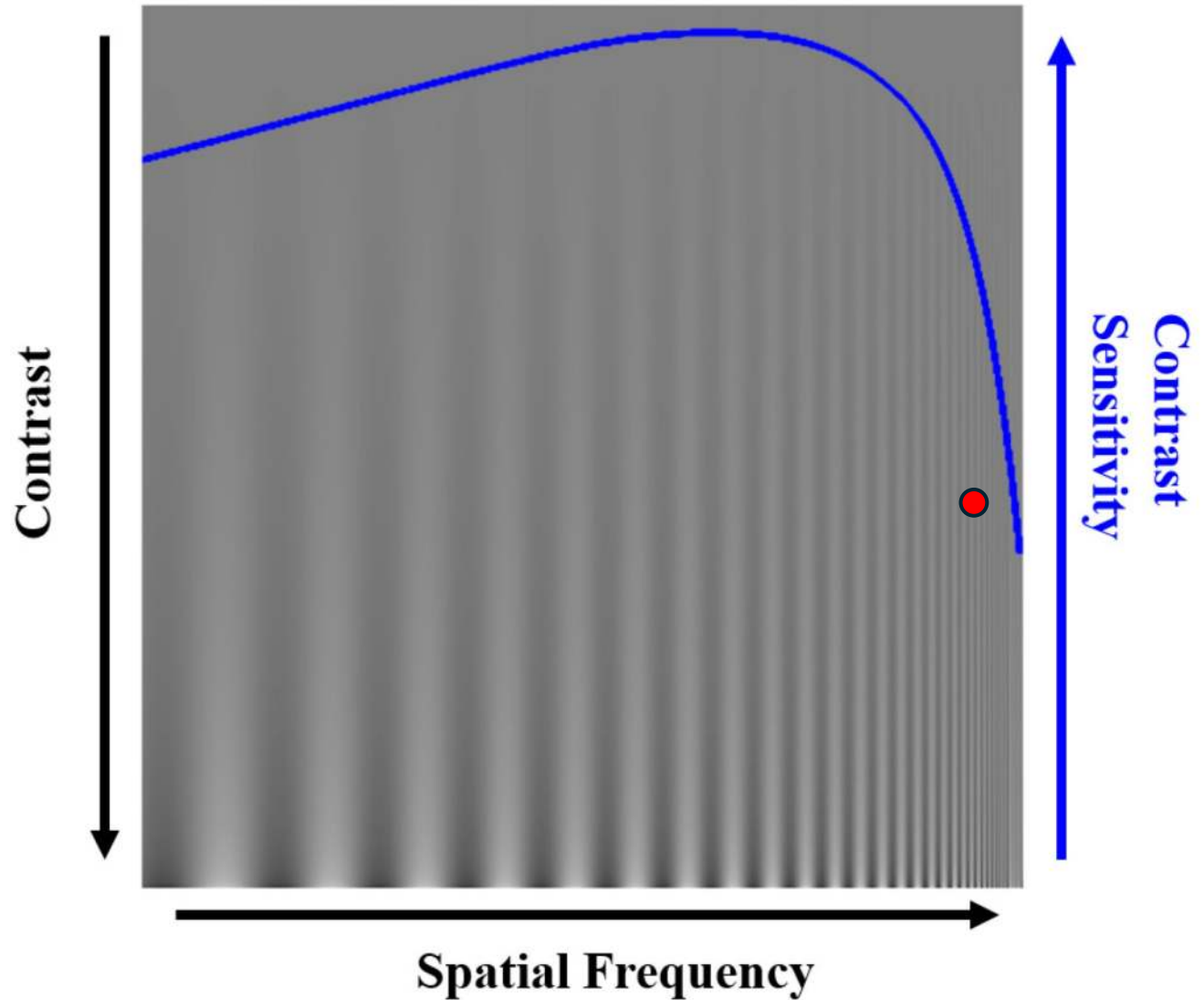
CC0; Leonhard Lenz



Achromatic Contrast Sensitivity



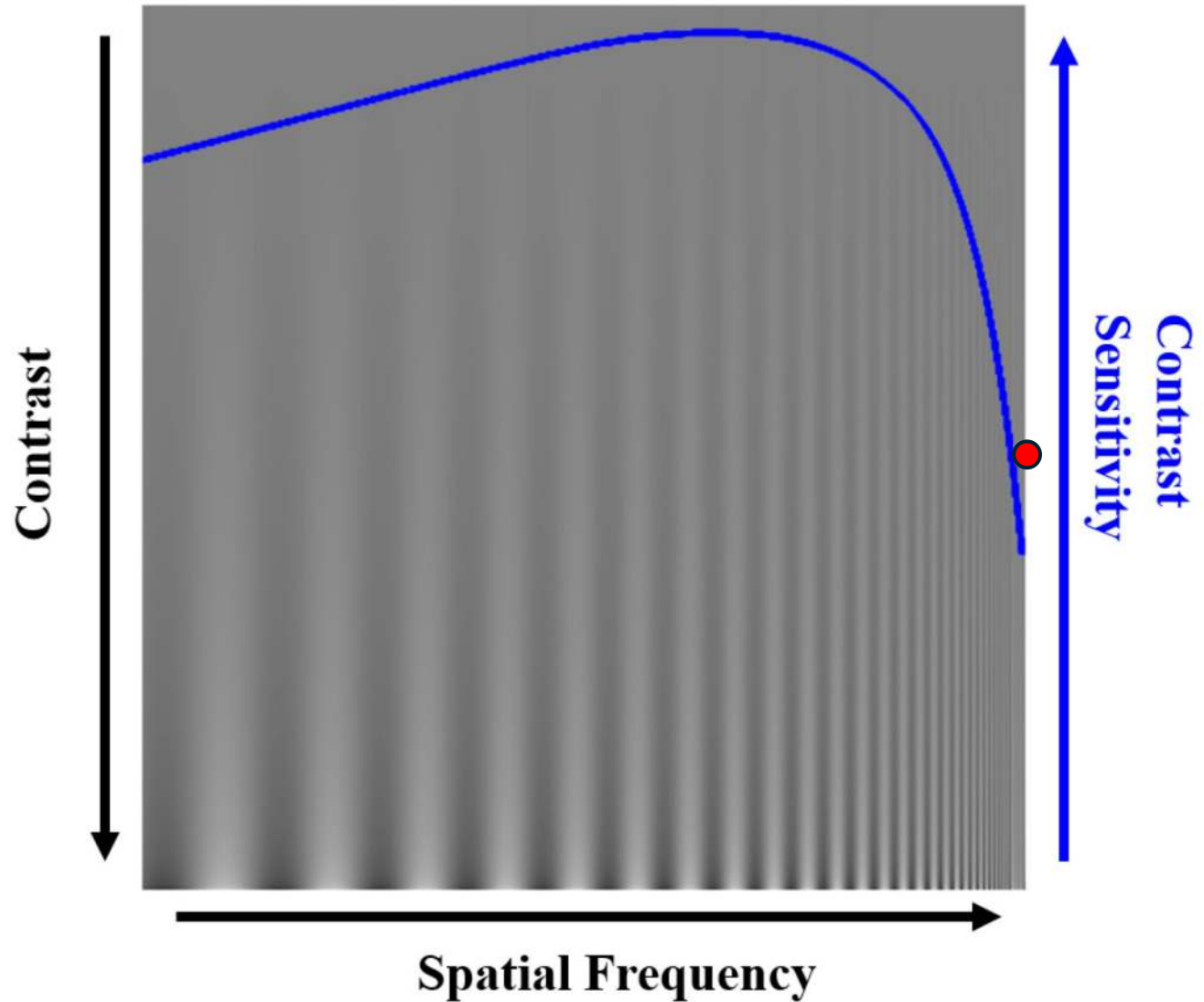
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Achromatic Contrast Sensitivity



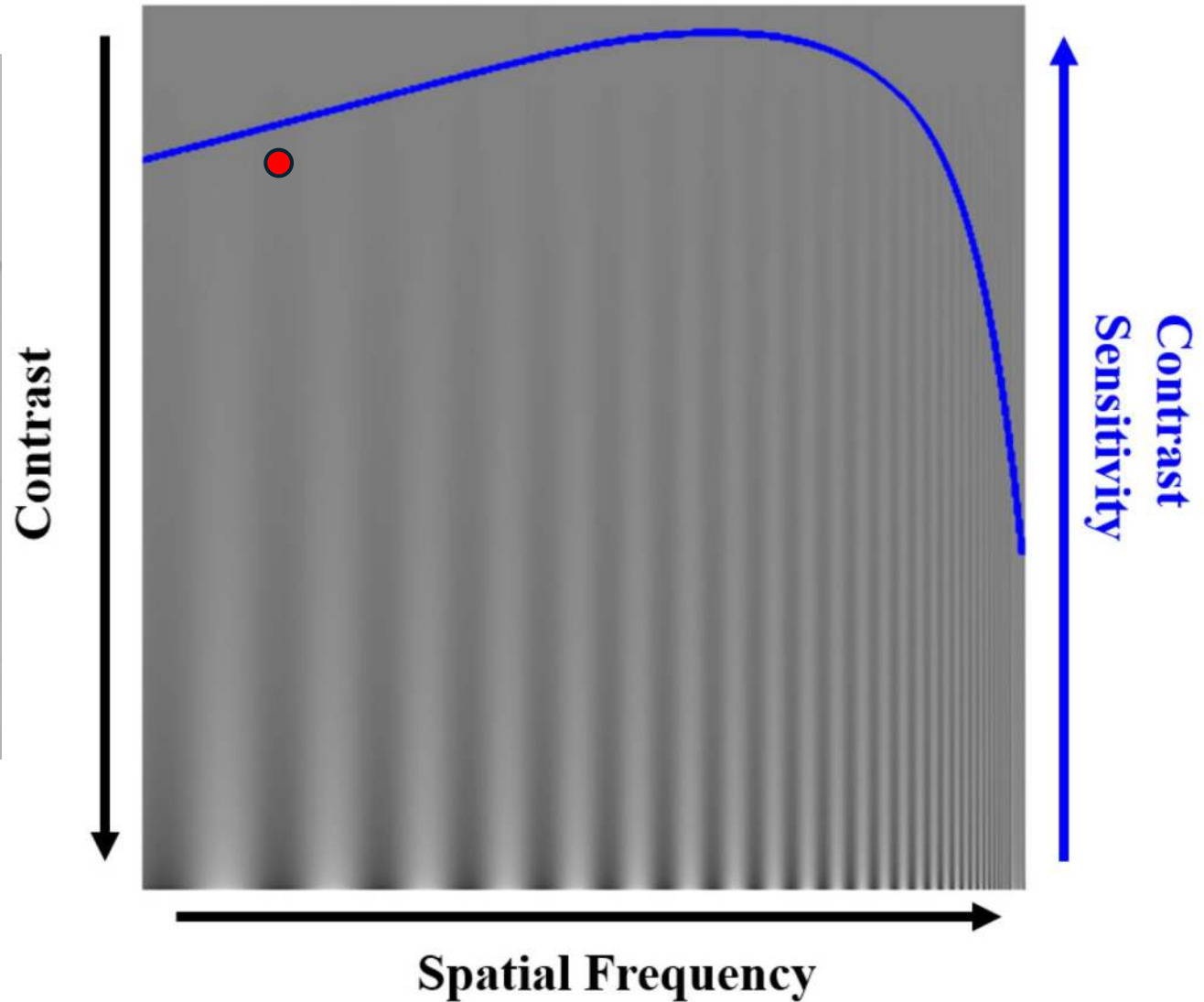
[CC-BY 2.0](#); Mark Heybo



Achromatic Contrast Sensitivity



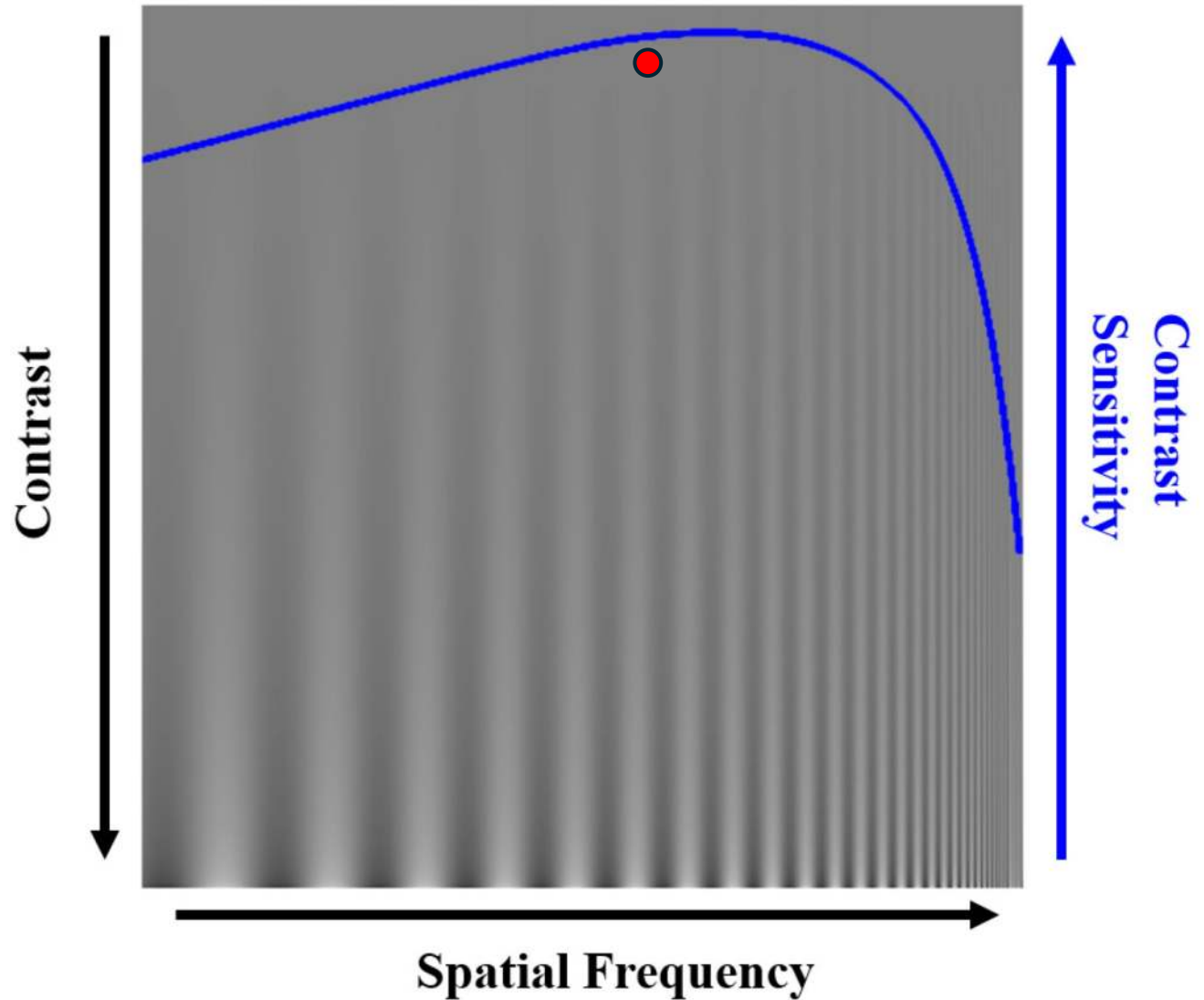
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Achromatic Contrast Sensitivity



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Achromatic Contrast Sensitivity

- Birds typically have much lower contrast sensitivity than mammals



Low Contrast



High Contrast

Achromatic Contrast Sensitivity

- Birds typically have much lower contrast sensitivity than mammals

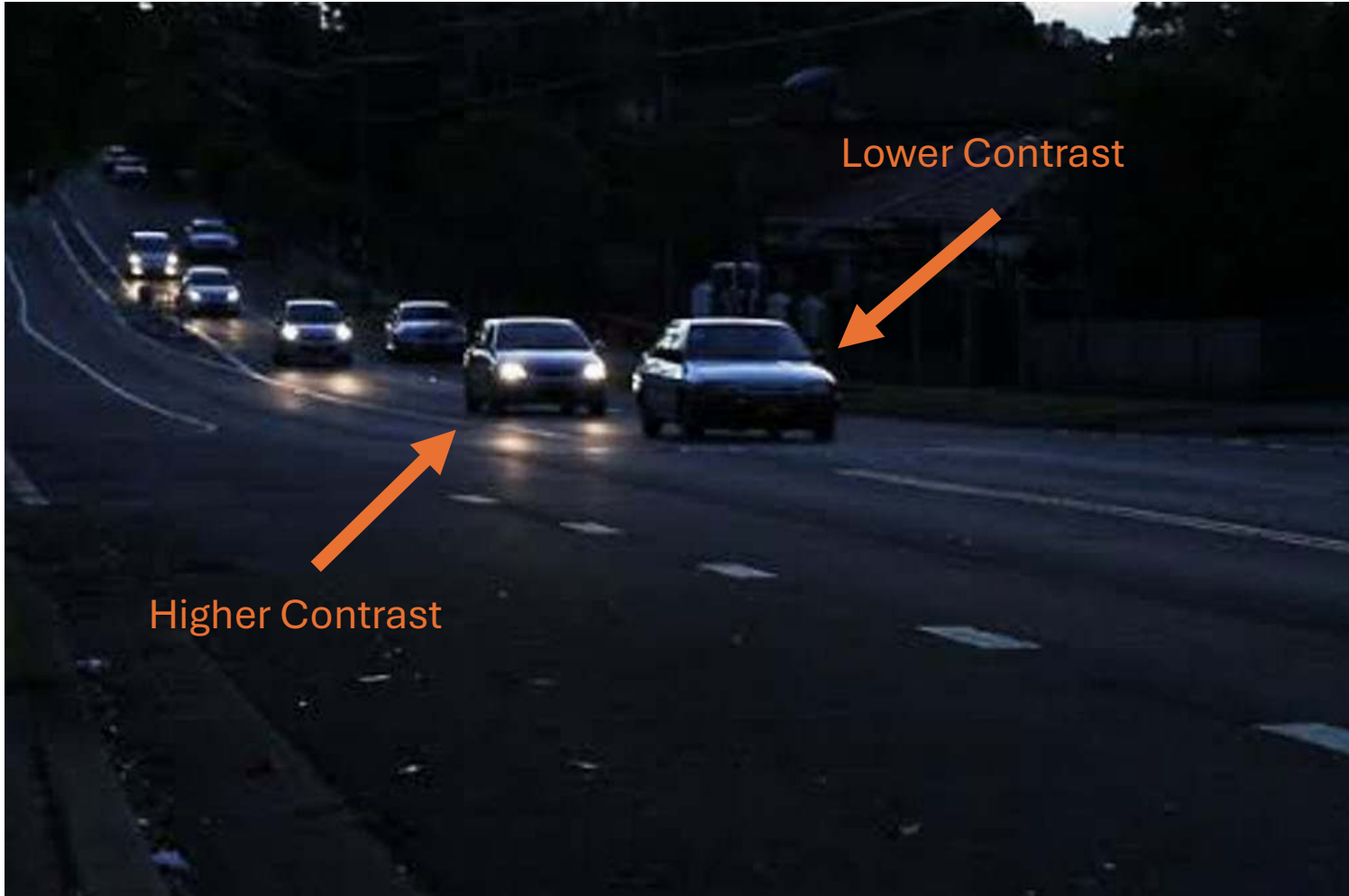


Low Contrast → We can see this duck.

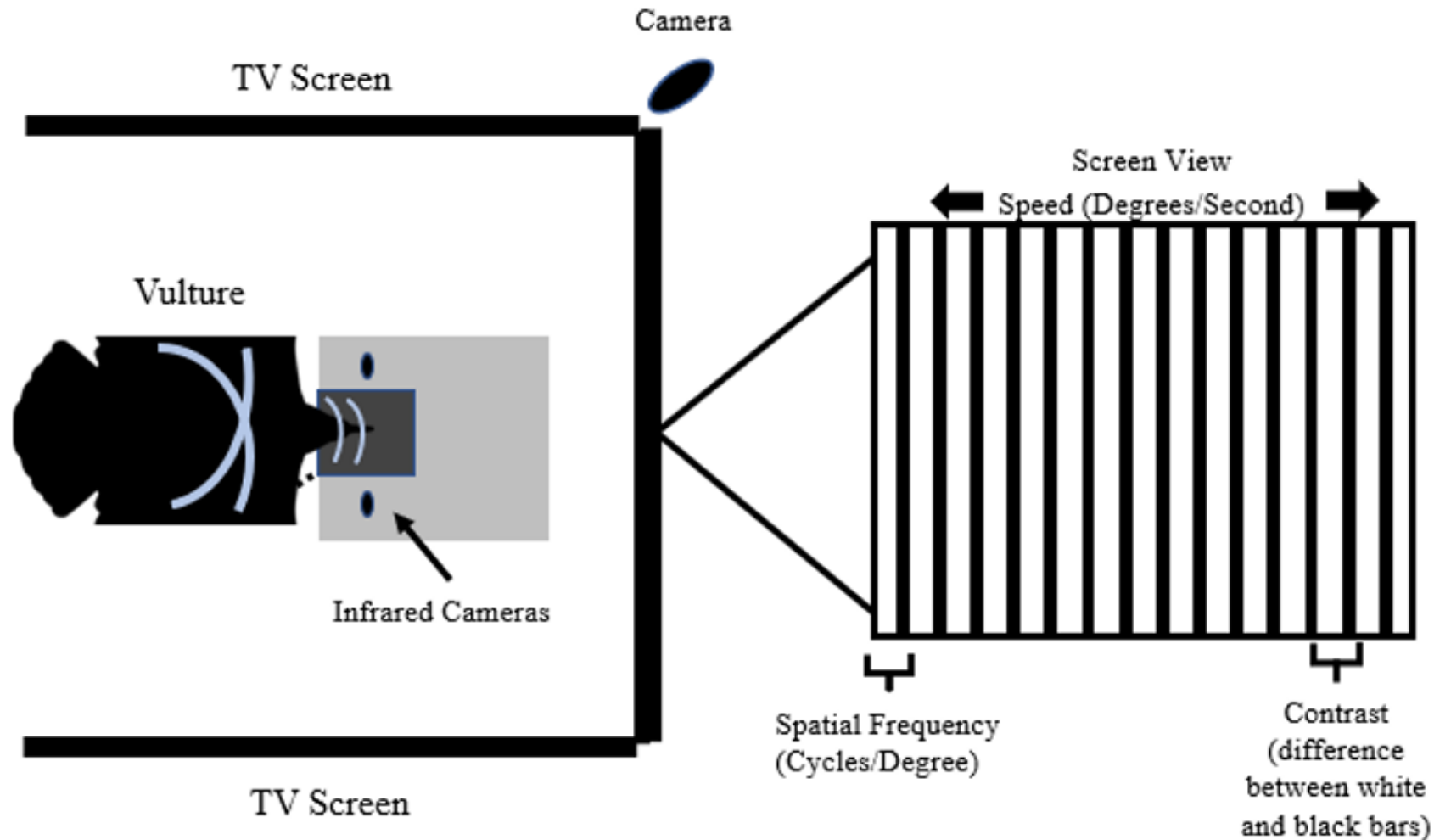


High Contrast → We can see this duck; birds can too.

Onboard Lights Improve Contrast!

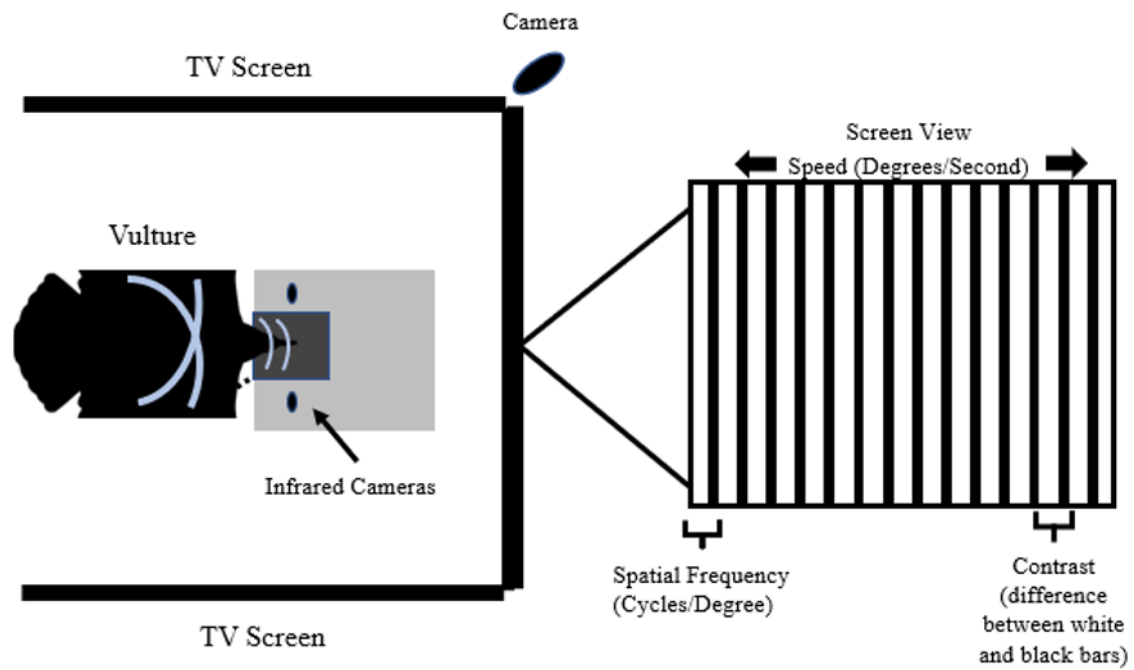


Method – Experimental Arena Top View



Method

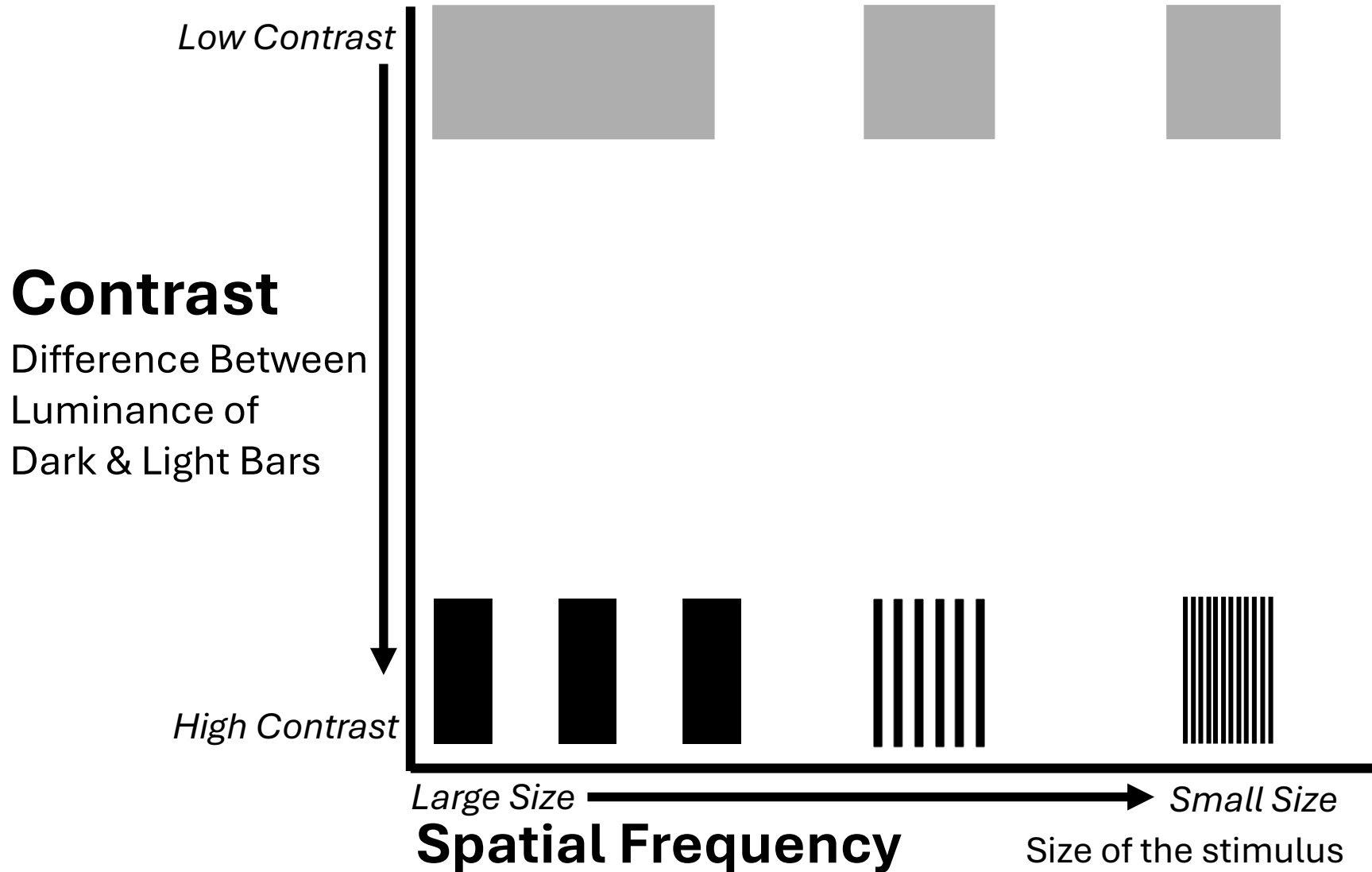
Top View



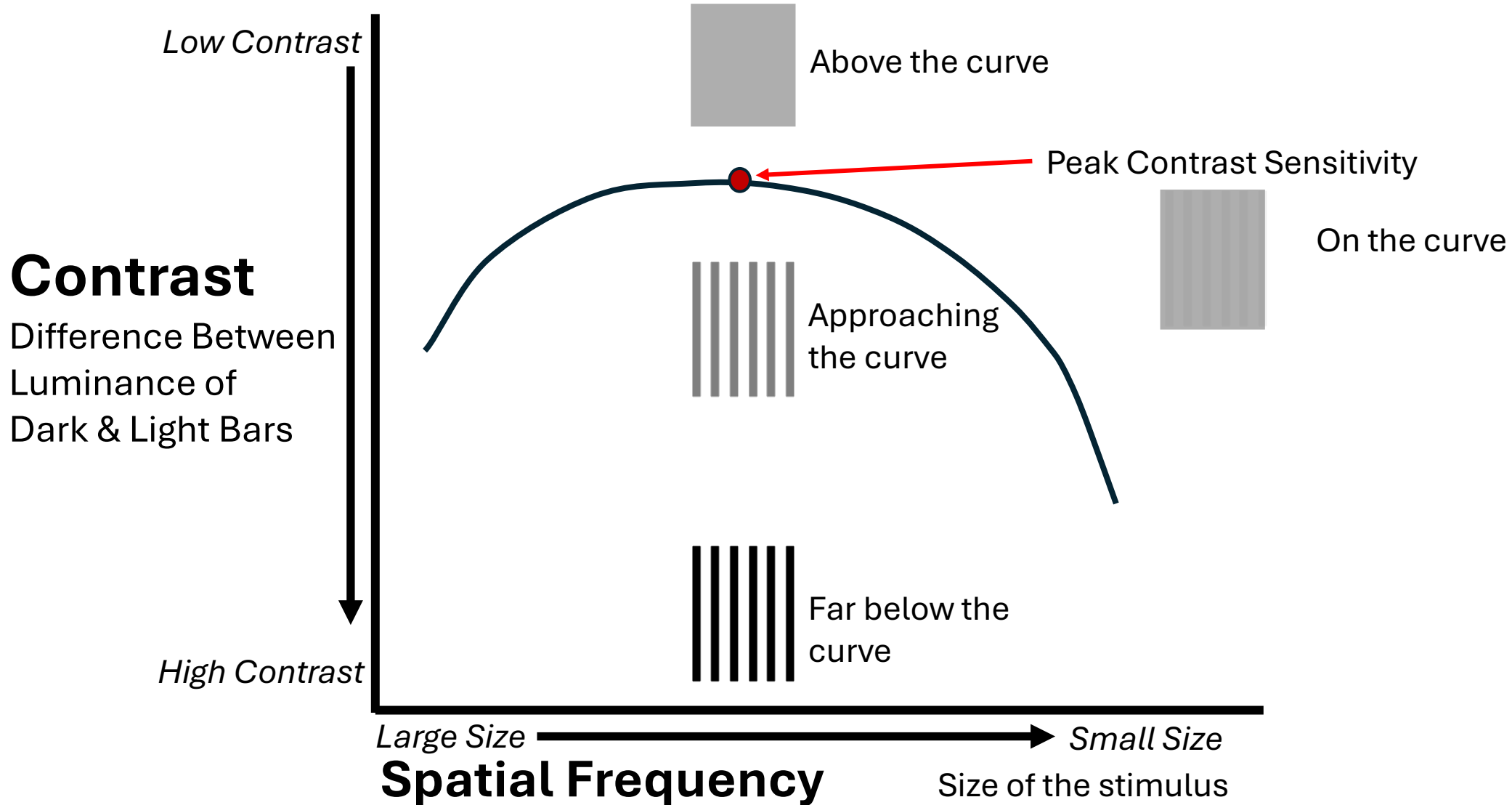
Optokinetic Response: Eye Movement = Detection



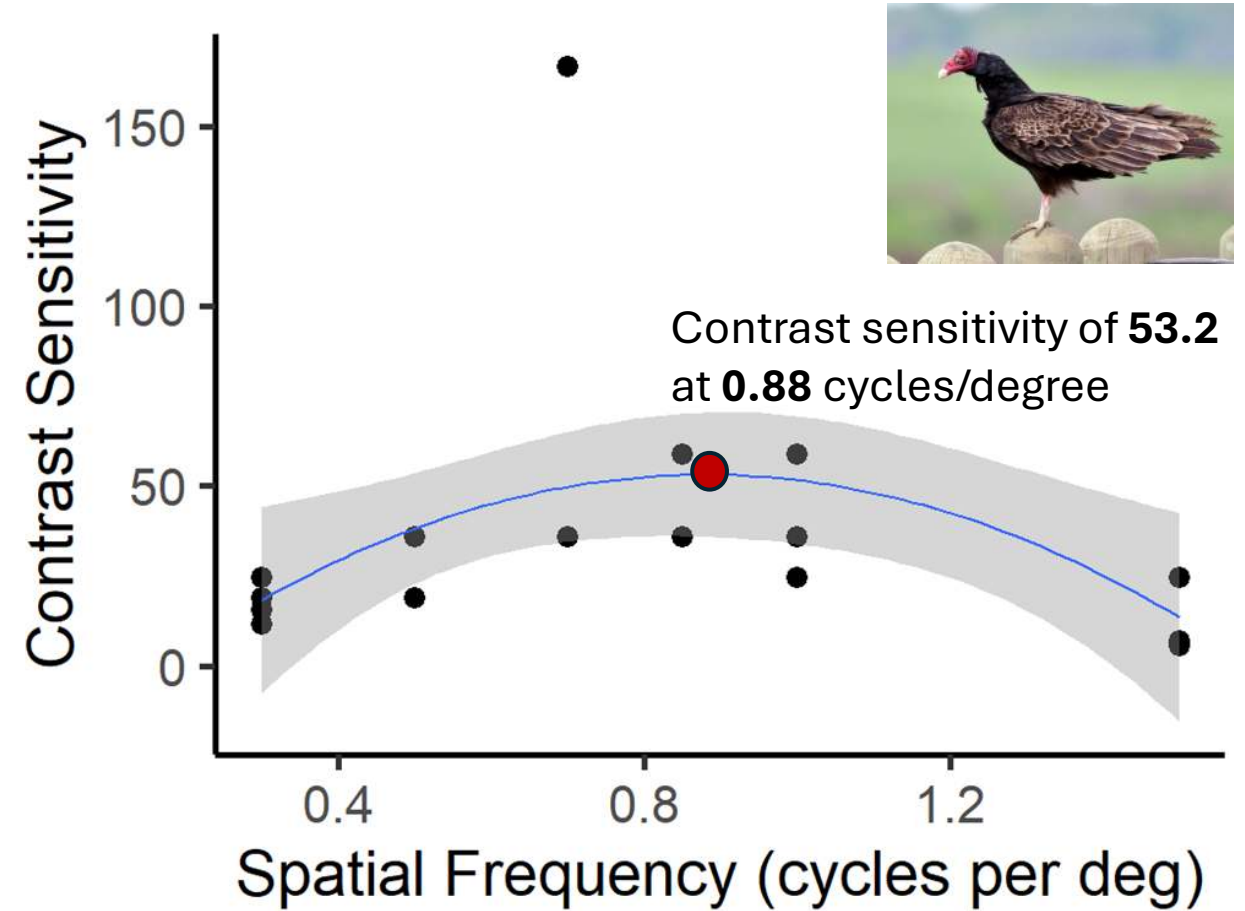
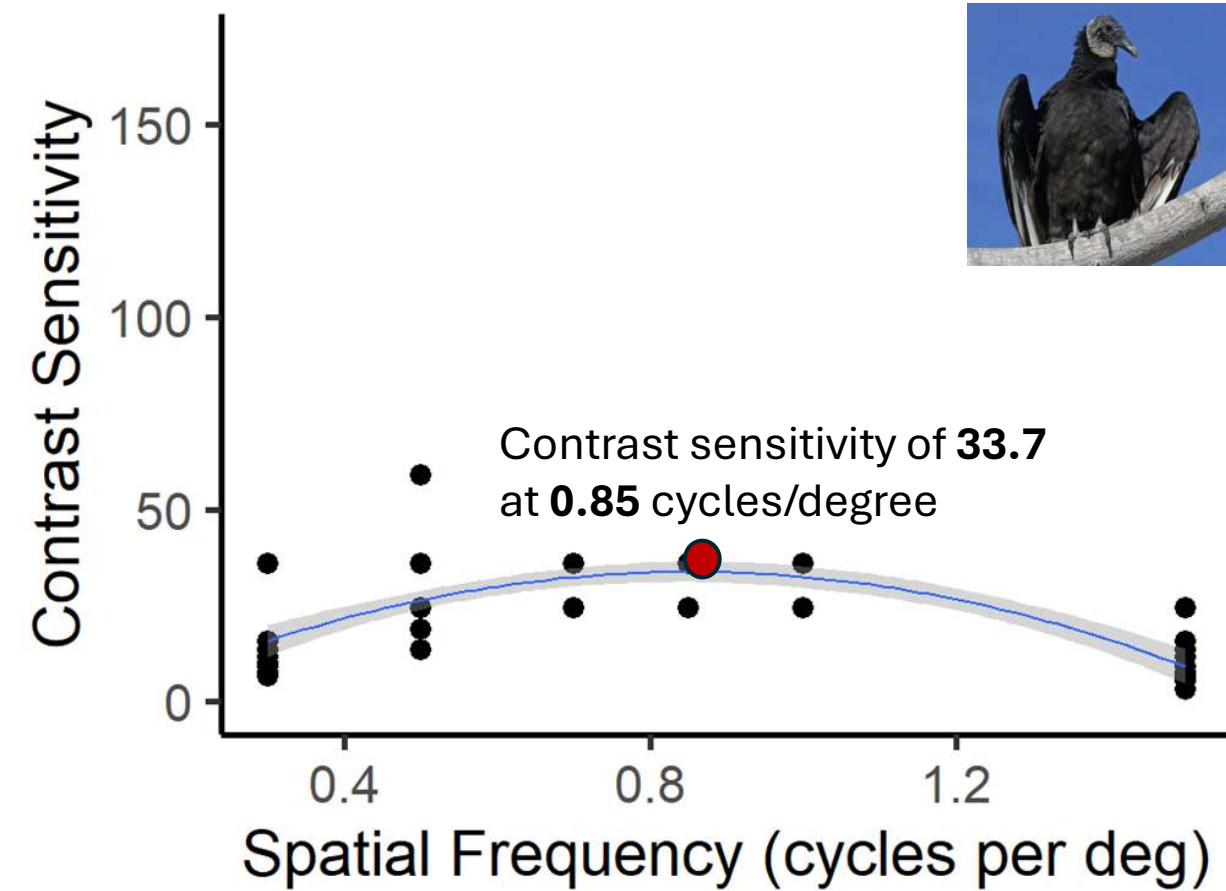
Interpreting a Contrast Sensitivity Curve

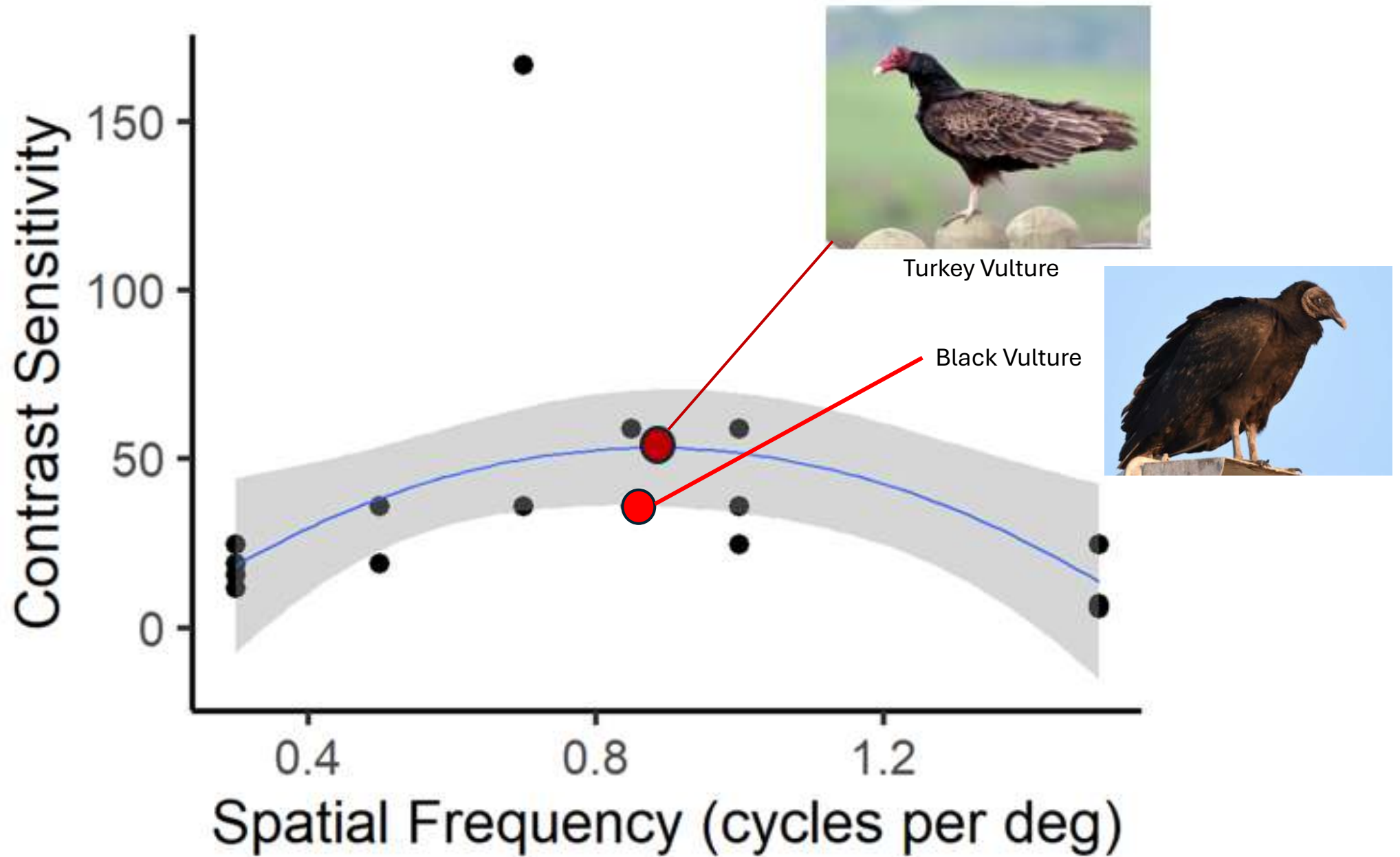


Interpreting a Contrast Sensitivity Curve

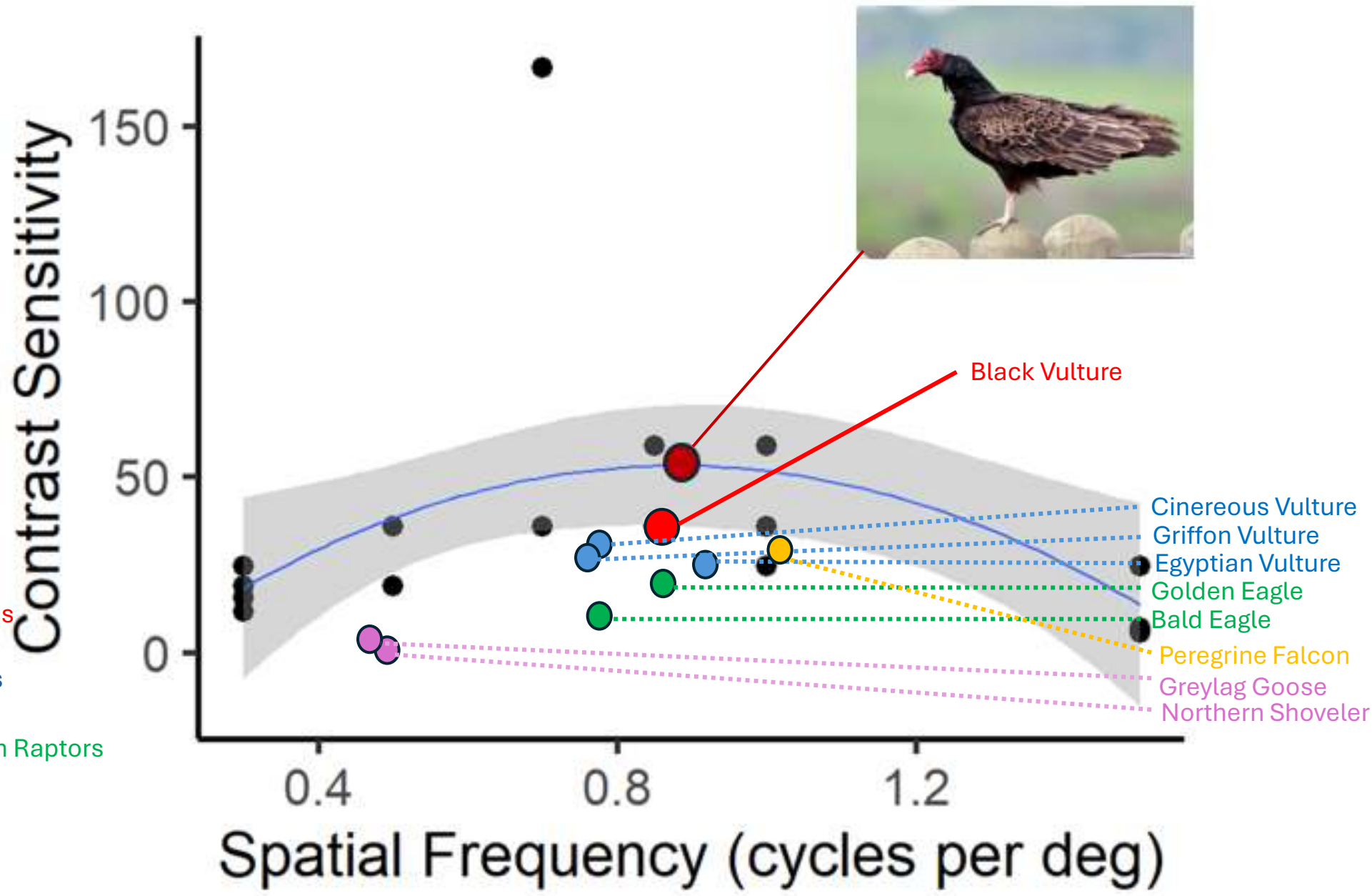


Vulture Contrast Sensitivity





- New World Vultures
- Old World Vultures
- Other Accipitriform Raptors
- Falcons
- Ducks & Geese



Ecological Mechanisms

- 1) Monitoring, following other vultures to carcasses



Public Domain, Brad Sutton, National Park Service

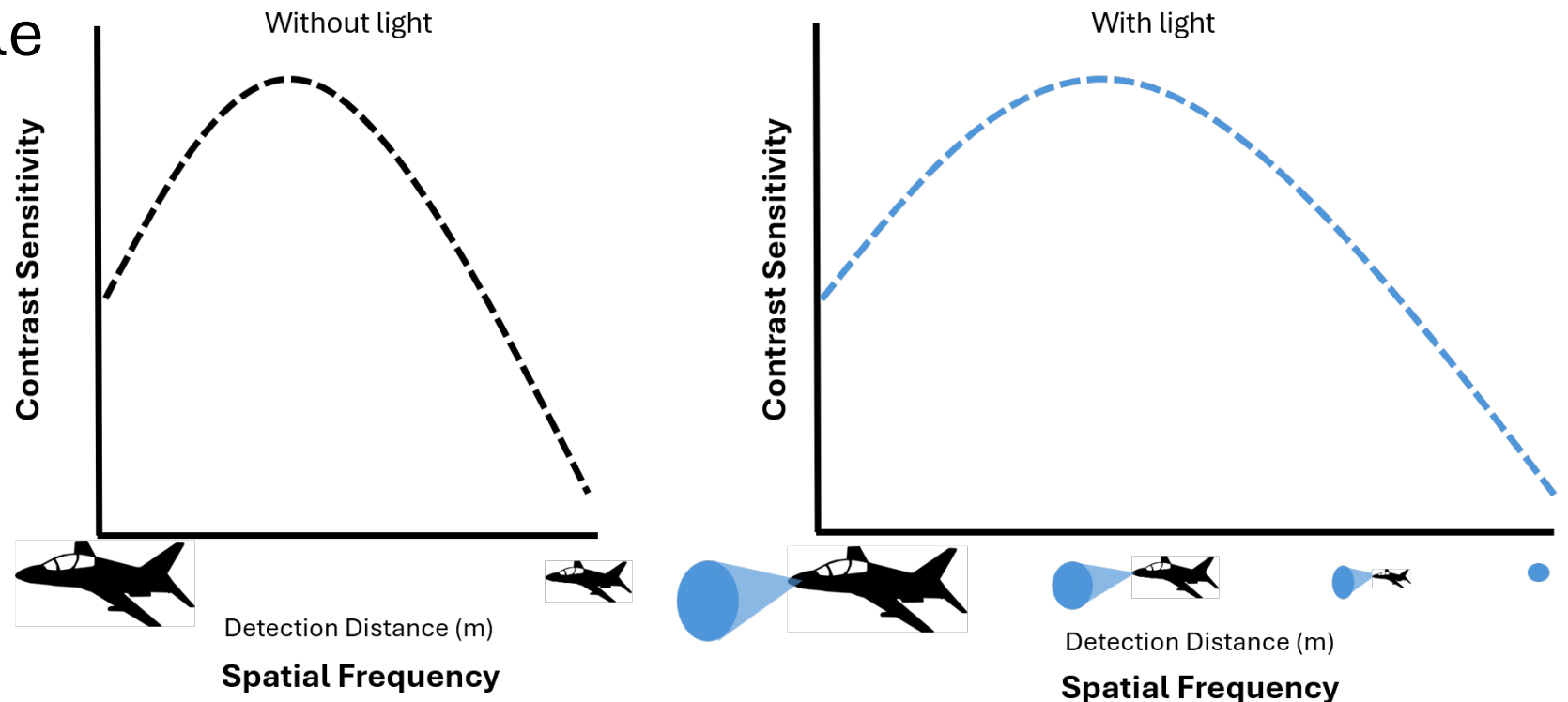
- 2) Carcasses at high altitude likely have very low contrast



© Bill Stockland

Implication for Bird Strikes

- Onboard lights do not need to be bright to increase visibility to vultures
- Even under low visibility conditions, onboard light should make aircraft more visible

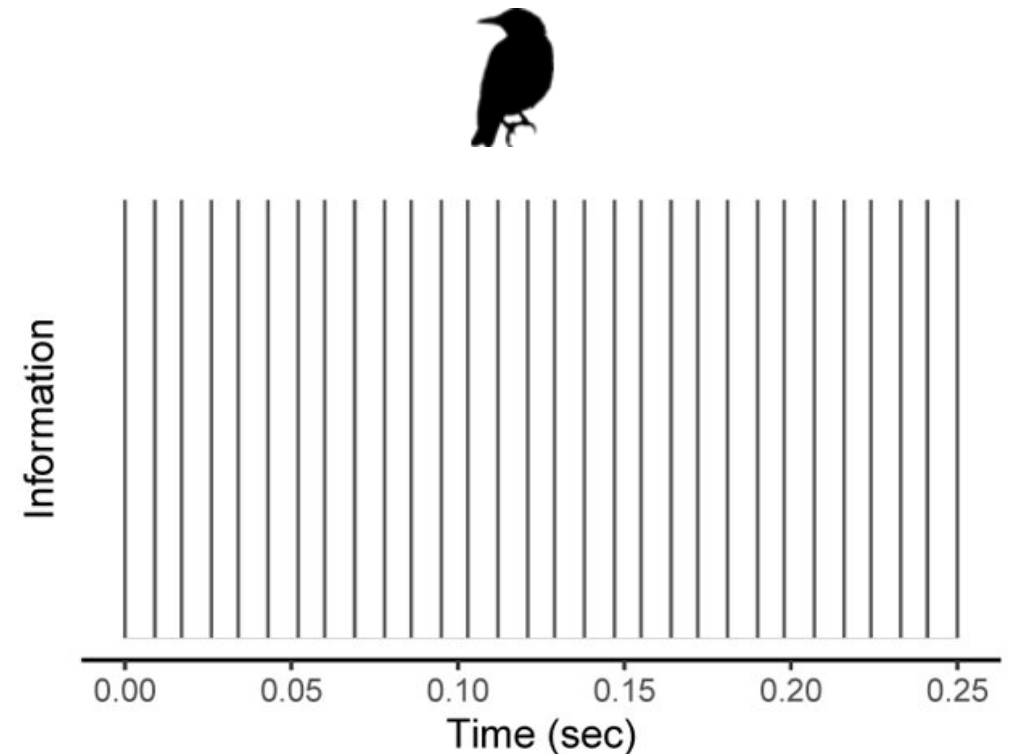
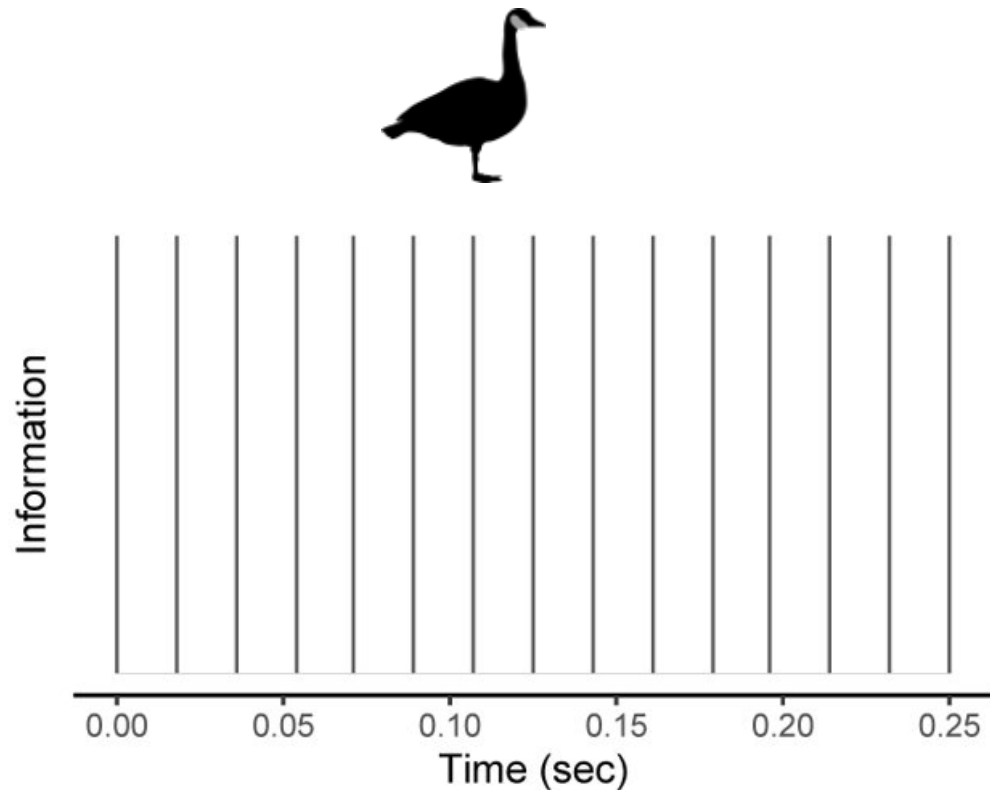


II. Temporal Visual Resolution

Detecting and Monitoring Fast-moving Objects

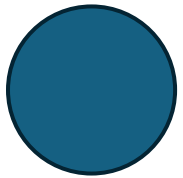
Temporal Visual Resolution

- How much visual information can be sampled before a collision is imminent

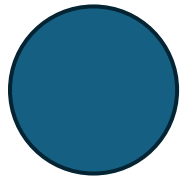


Flicker Fusion Frequency

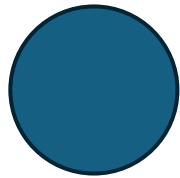
- Frequency at which a pulsing light appears steady
- Humans: 50 – 90 Hz



1 Hz



2 Hz



120 Hz

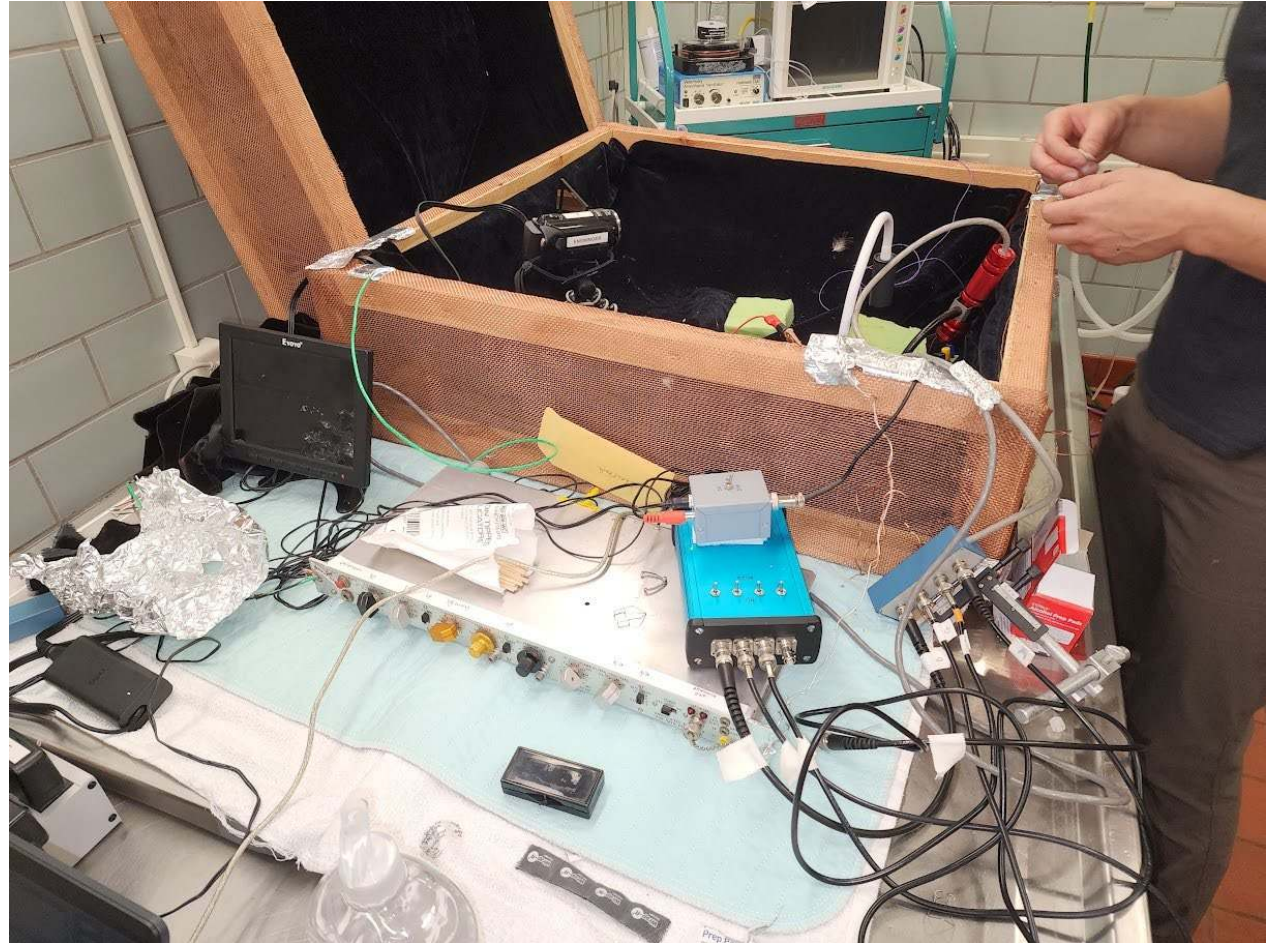


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120 Hz (United States)

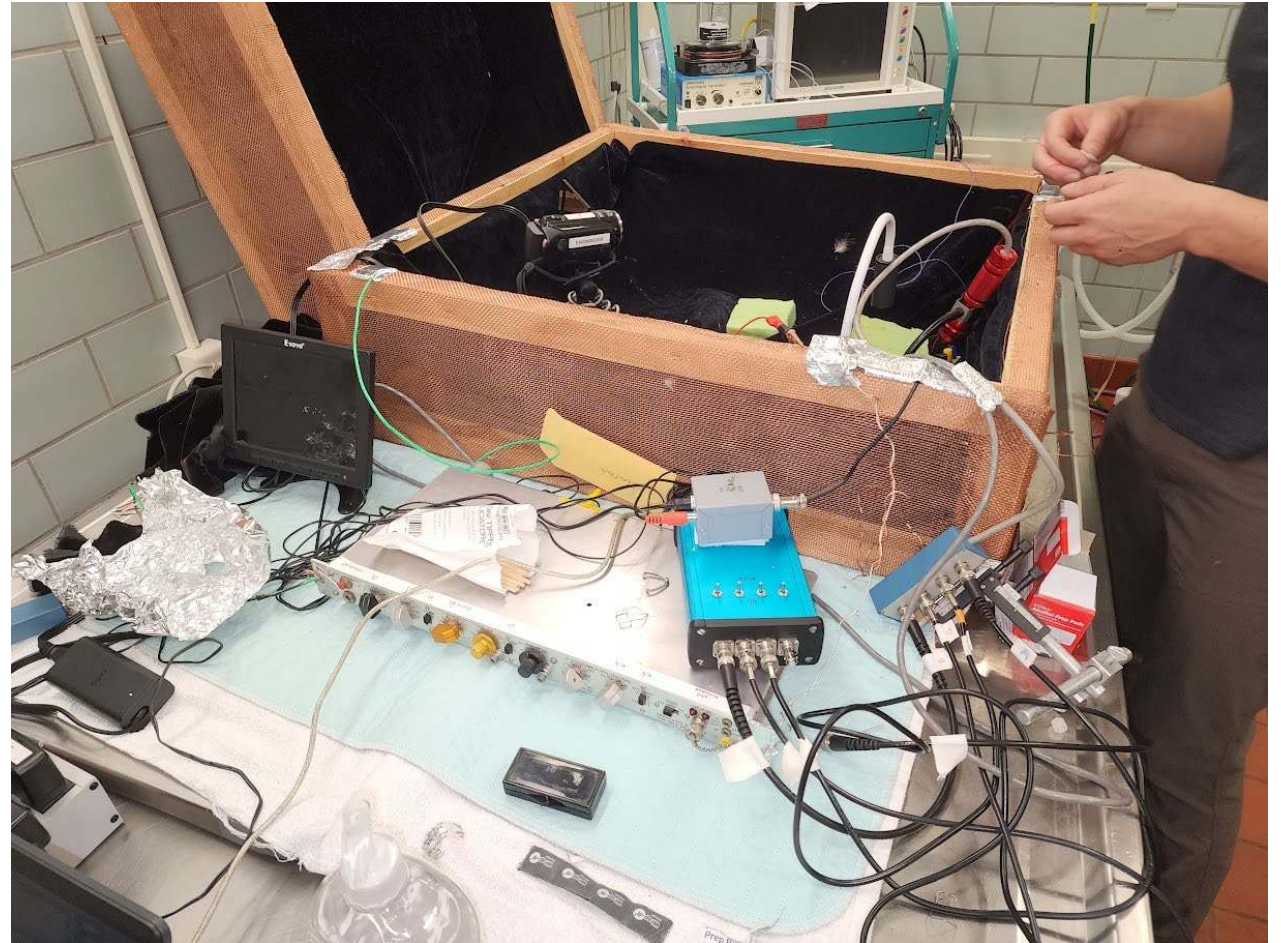
Method – How to Measure a Bird's FFF

- Electroretinograms
- Anesthesia Protocols

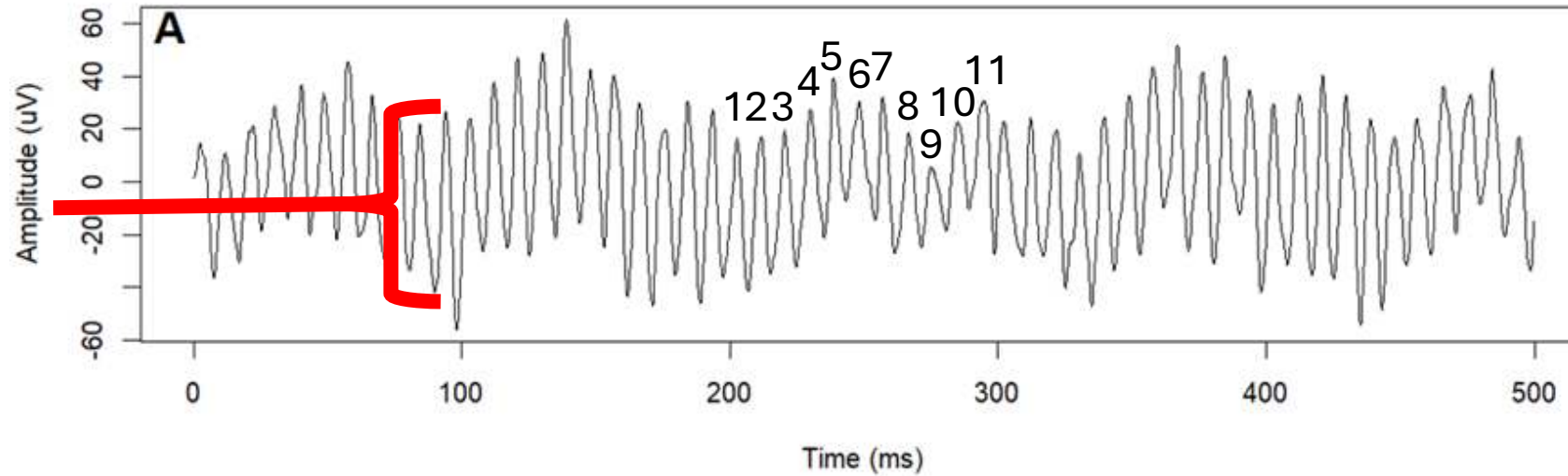


Method – How to Measure a Bird's FFF

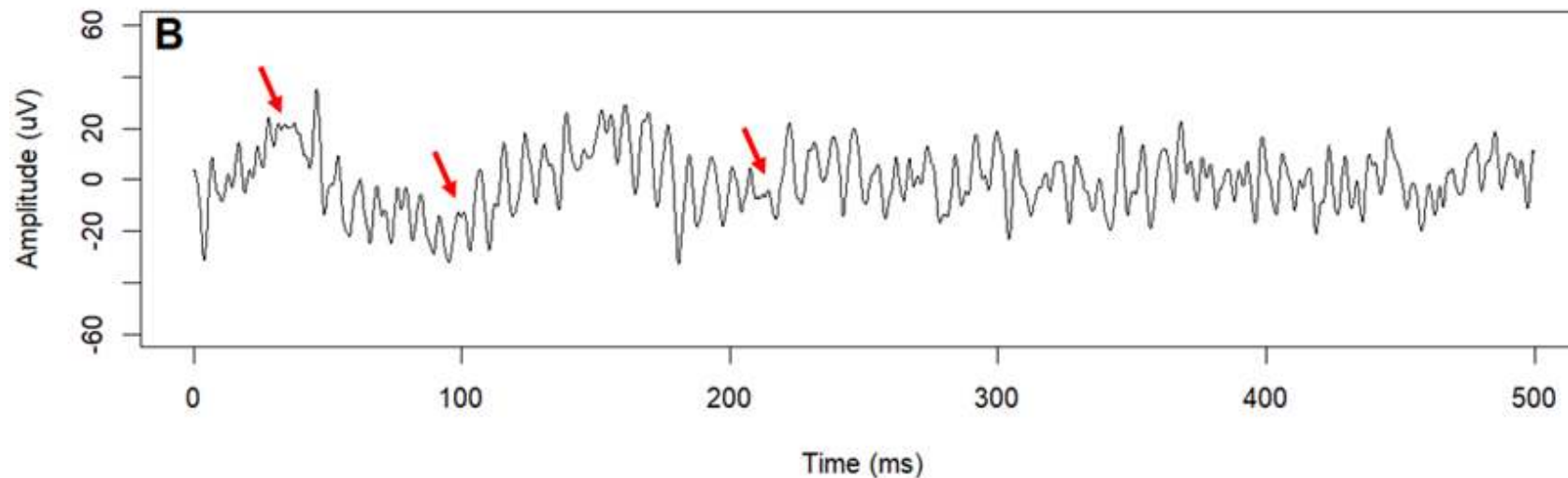
- Electroretinograms
- Anesthesia Protocols
- We measured FFFs for Red, Green, Blue, and White light



Retinal Response Curves

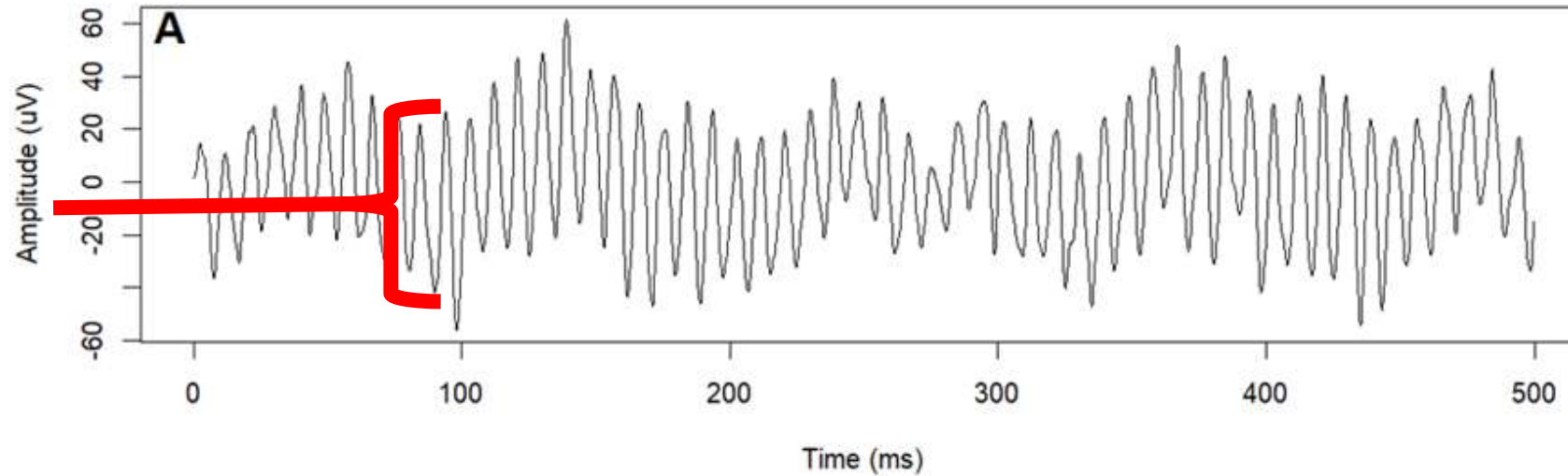


110 Hz
Response



130 Hz
Response

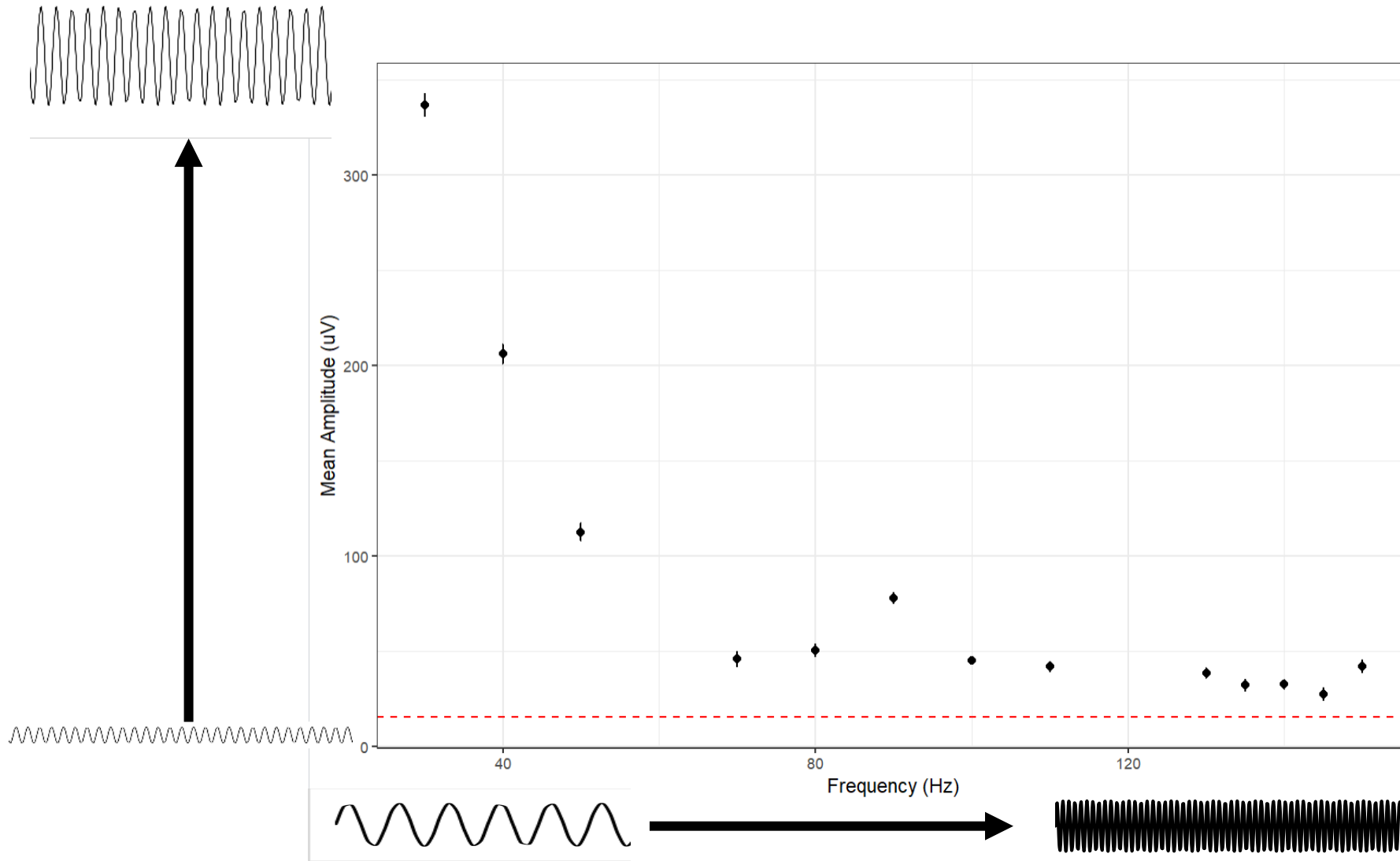
Retinal Response Curves



110 Hz
Response

Amplitude is $\sim 60\mu\text{V}$
for this wave.

Magnitude of Retinal Responses (e.g., amplitude of retina's response as frequency increases)



Mean Vulture Flicker Fusion Frequencies

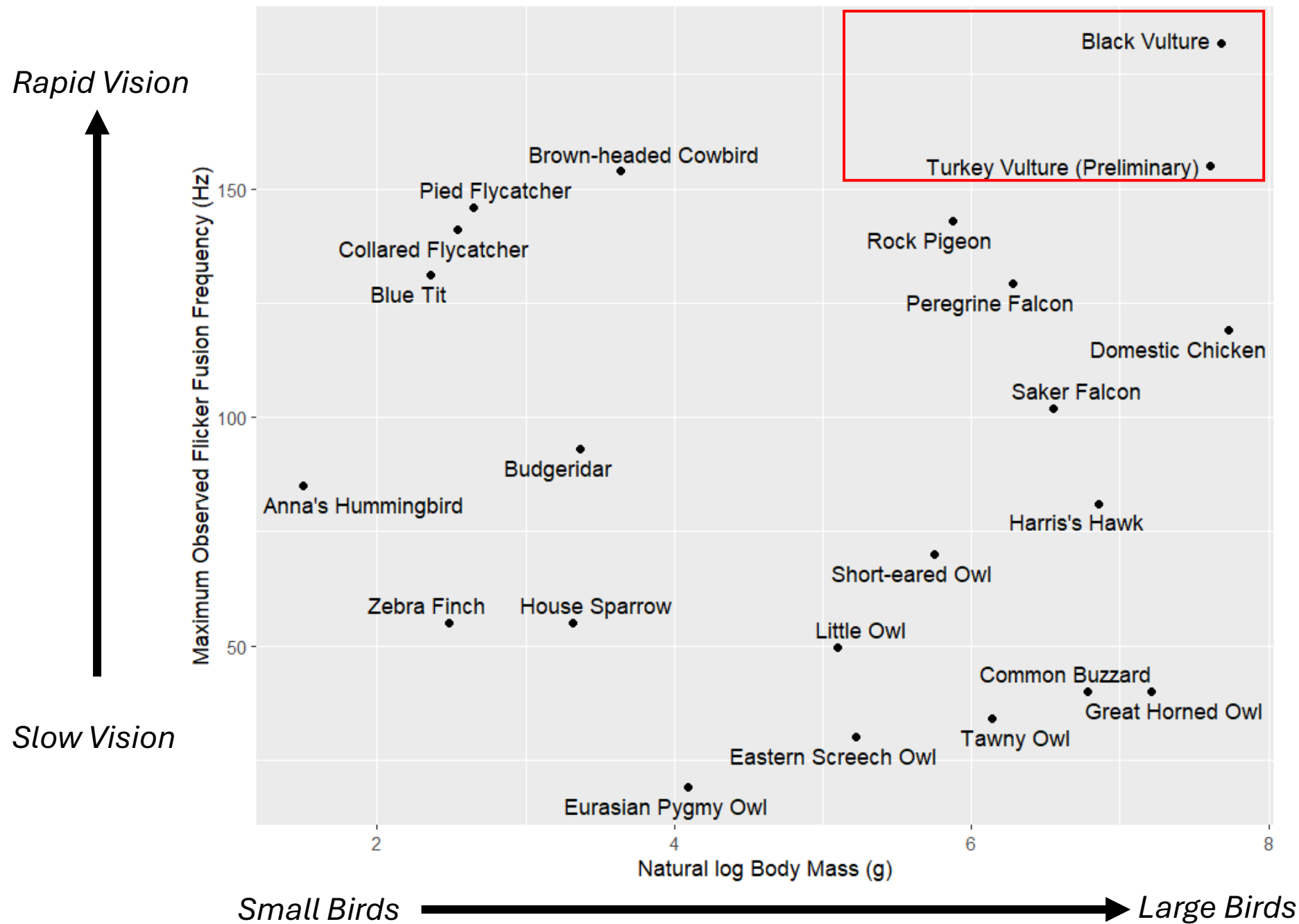
Black Vulture

- Red: **157.5 Hz**
- Green: **155.4 Hz**
- Blue: **115.3 Hz**
- White: **130.9 Hz**

Turkey Vulture (Preliminary)

- Red: **142 Hz**
- Green: **140 Hz**
- Blue: **90 Hz**
- White: **125 Hz**

- Individual FFFs reached as high as 181.8 Hz



Possible Ecological Mechanisms

- Need to find and monitor rising thermals



Public Domain, published by NASA

Possible Ecological Mechanisms

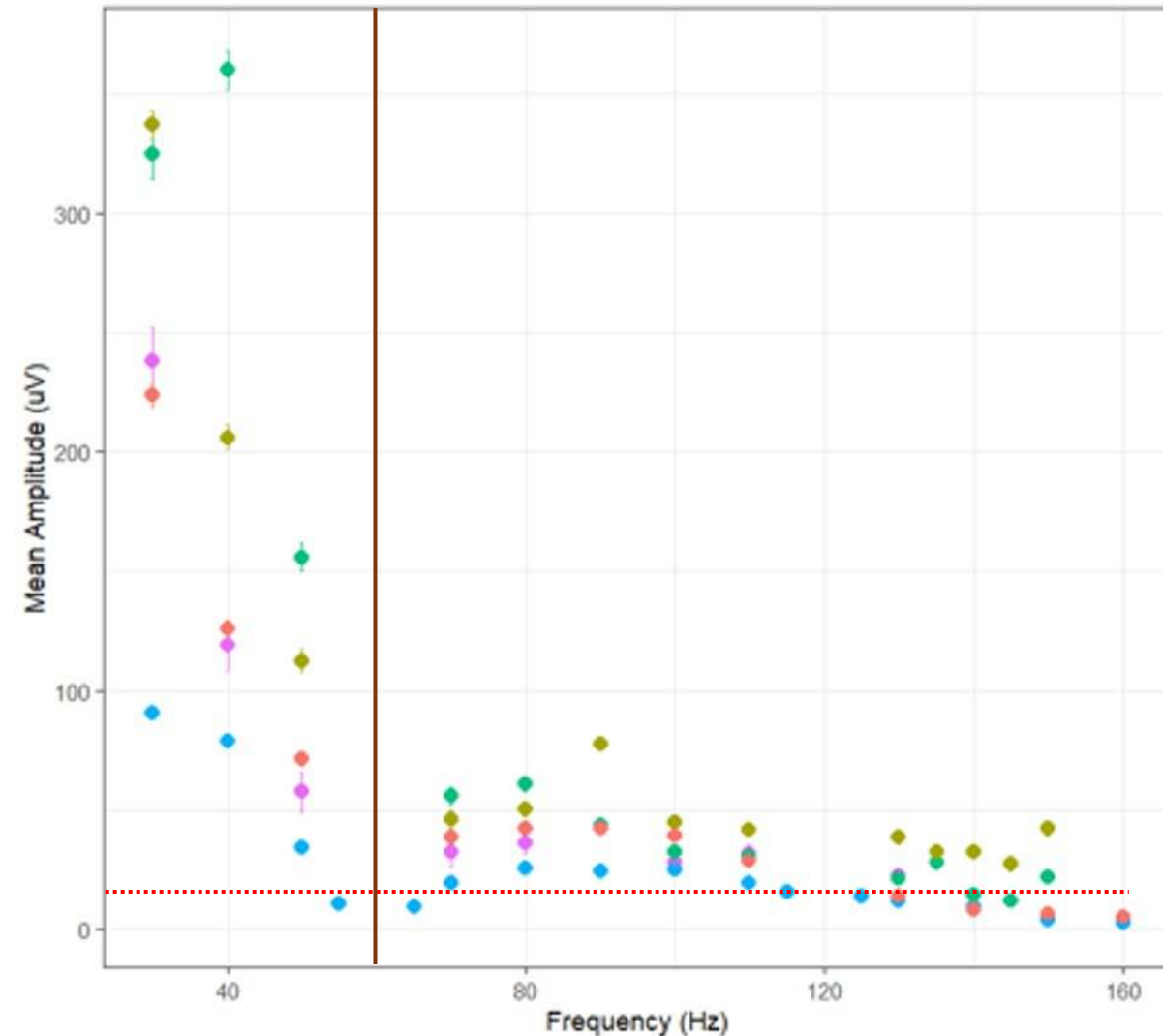
- Need to find and monitor rising thermals
- Conspecific collision avoidance



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Implications for Bird Strikes

- These birds are still having *strong* retinal responses at achievable, high frequencies outside of human vision.



General Outcomes

- For large, non-agile, scavengers, vulture vision outperforms all expectations, especially in the temporal dimension.
- Should be able to discriminate extremely well against the background, even in low light.
- Have remarkably fast vision, especially for red and green light.

Moving forward with New World Vultures

- Behavioral tests:
 - Lighting Choice Test
 - Simulated Vehicle Approaches



This project is supported by:



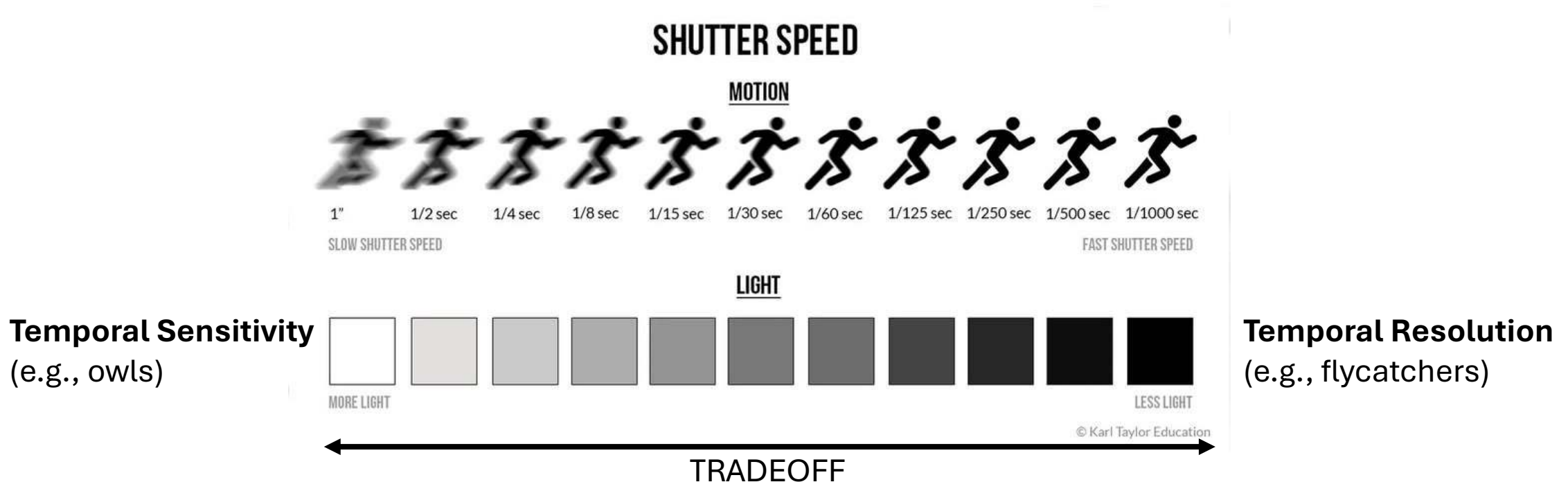
Questions?



Appendix

Temporal Visual Resolution

- How much visual information is obtained and processed over a given unit of time
- High Temporal Visual Resolution = Low Motion Blur



Species	# Strikes	% Damaging Strikes*	Visual Fields	Visual Acuity	Achromatic Contrast Sensitivity	Cone Sensitivities	Temporal Resolution
Turkey Vulture	1163	48.7	Yes	Yes	No	No	No
Black Vulture	353	62.6	No	Yes	No	No	No
Red-tailed Hawk	4048	12.9	Yes	No	No	No	No
Swainson’s Hawk	240	15.0	No	No	No	No	No
Broad-winged Hawk	60	33.3	No	No	No	No	No
Ferruginous Hawk	70	7.1	No	No	No	No	No
Bald Eagle	492	36.4	Yes	Yes	Yes	Yes	No
Golden Eagle	37	32.4	Yes	Yes	Yes	Yes	No
Osprey	628	21.3	No	No	No	No	No
Egyptian Vulture	NA	NA	No	Yes	Yes	No	No
Indian Vulture	NA	NA	No	Yes	No	No	No
Griffon Vulture	NA	NA	Yes	Yes	Yes	No	No
White-backed Vulture	NA	NA	Yes	No	No	No	No
White-headed Vulture	NA	NA	Yes	No	No	No	No
Cinerous Vulture	NA	NA	No	No	Yes	No	No

*% Damaging Strikes is reported as the percentage of damaging strikes (1990 – 2023) for each species, per Dolbeer et al. 2024

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