(Don't) Shake a Tail Feather: Function of American Goldfinch Tails During Slow Flight

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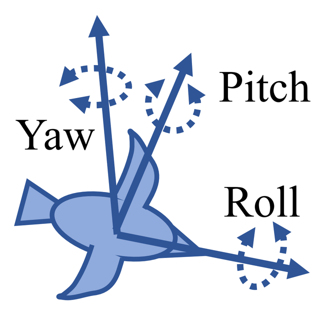
Introduction

Behavior

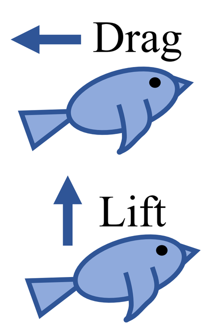
- Birds **increase tail movements** in the presence of **predators** or a **potential mate**.[1] However, how these movements affect flight is unclear.

Maneuverability



- Tail function during **high speed flight** assists in **pitch and roll** movements.[2]
- Theory **predicts** that at **slow** speeds, the tail is used to offset an **upward pitching** caused by the wings in downstroke.[3,4]

Aerodynamic Forces



- In **steady flight**, a furled tail **reduces body drag.**[5]
- At **medium flight speeds**, tail produces **lift and drag** during bounding phases.[6]

Specific Aim

- Although there have been many **observations** and **predictions** of tail function in different **flight behaviors,** there are few studies of tail function in **wild birds** during **slow flight**.
- **American Goldfinches** *(Spinus tristis*) were studied for their **agnostic** behaviors and **dominant/submissive** relationships.[7]

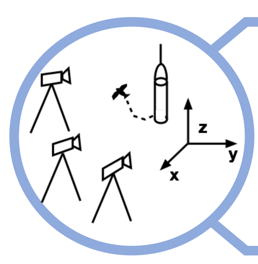
- Other birds studied for comparison included Tufted Titmice, Dark Eyed Junco, Song Sparrow, Northern Cardinal, and Eastern Towhee.

Hypotheses and Predictions

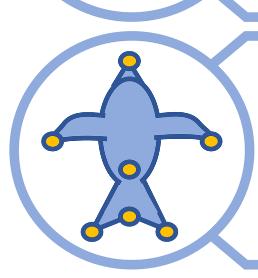
Tail Function Hypotheses

Behavioral	Maneuverability	Aerodynamics
Increase in tail **surface area** in the presence of competitors would indicate **signaling**.	Increased **surface area** and **angle of attack** through **downstroke** while turning	Increase of tail **spread angle** and **angle of attack** while landing to produce drag.

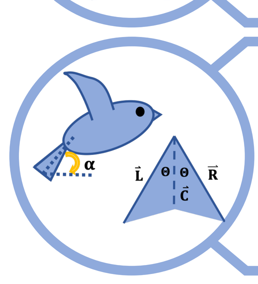
Methods



Recorded birds during landing, take off, and slow flight at 250fps with three synchronized Edgertronic cameras.



Digitized bill, rump, tail, and wing tips. This put the birds into a 3D volume to analyze movements.



Calculated kinematic values of tail AoA, tail spread angle, and tail area (A), which contribute to drag and lift.

Tail Angle of Attack

Angle of Attack (AoA) was measured by using the dot product to find the angle between two vectors: the tail plane and the airflow velocity.

Tail Surface Area

The tail was modeled as two triangles, right and left halves. For each triangle, the area and spread angles were calculated. The two halves were then added together.

Drag $\propto C_D*A*V^2$ **Lift** $\propto C_L*A*V^2$

When using their wings to **decelerate**, wild goldfinches use a **higher tail angle of attack** to produce additional **drag** and further **reduce flight speed.**

When approaching a **competitor**, they spread their tail more, which could provide **additional drag** and may also be a **competitive signal**.

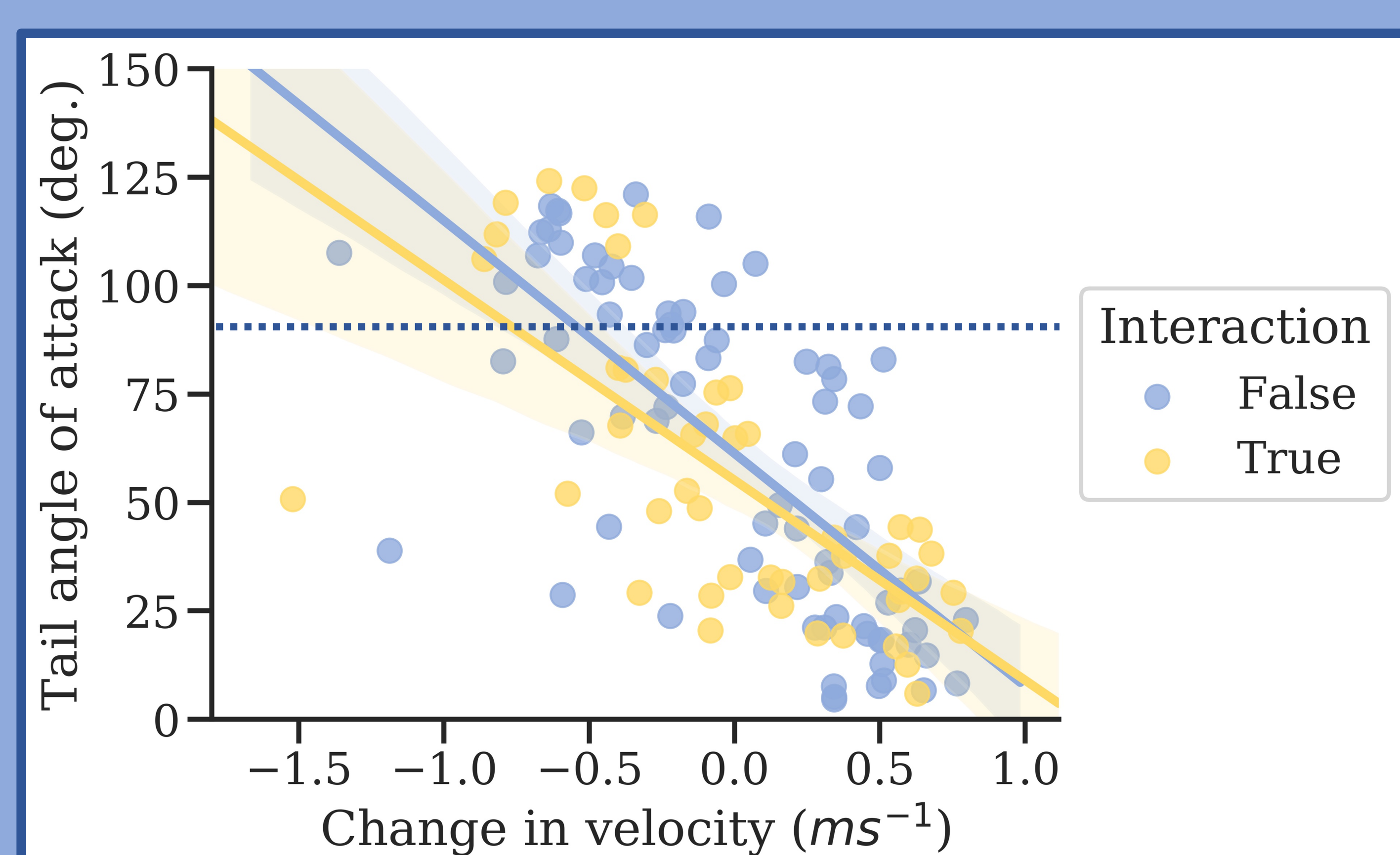


Figure 1. Median tail angle of attack of American Goldfinches decreases as birds switch from decelerating to accelerating wingbeats. Angle of attack near 90 degrees would produce maximum drag.

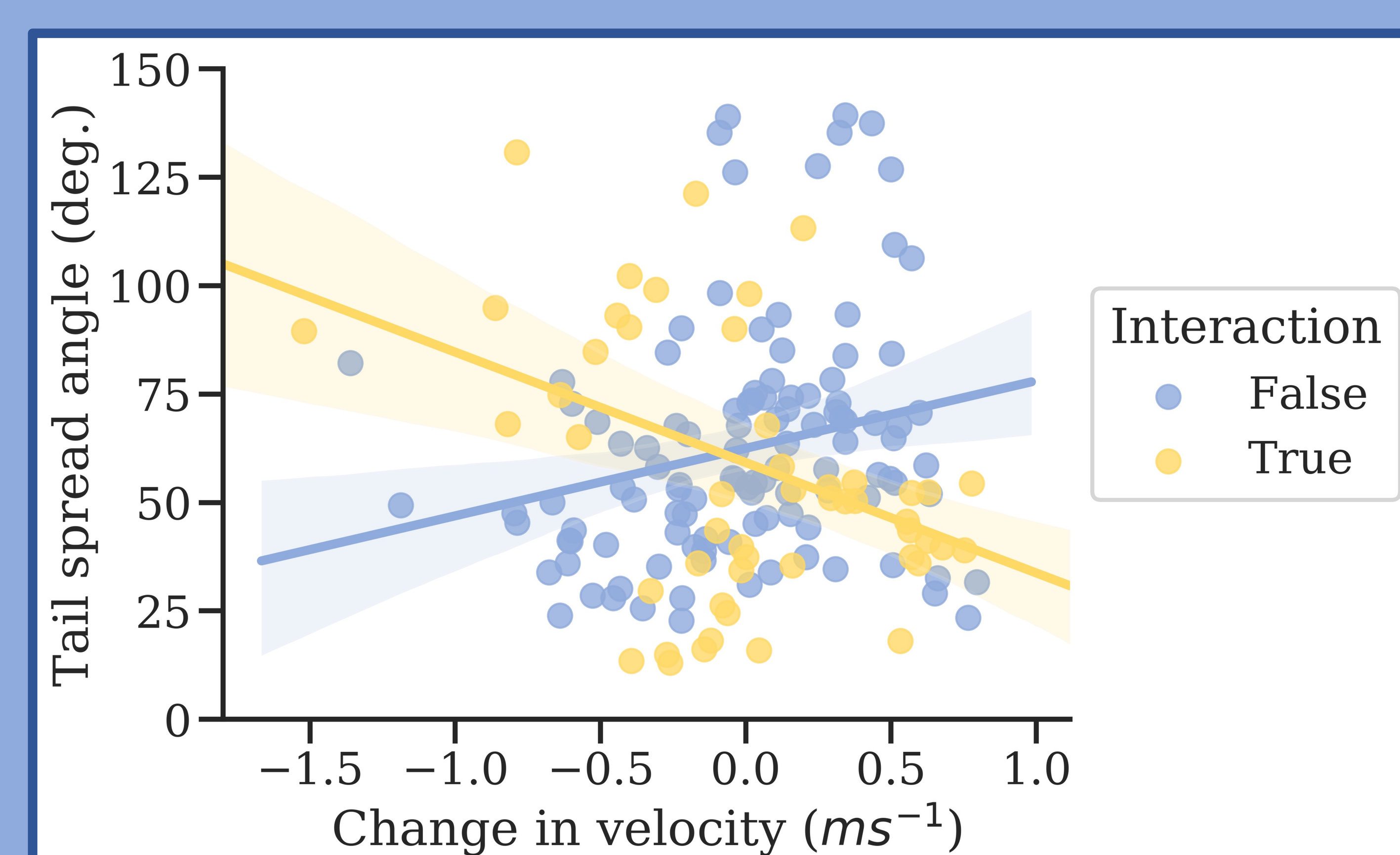


Figure 2. Median tail spread angle of American Goldfinches decreases as birds switch from decelerating to accelerating wingbeats if the bird is interacting with another bird, but not if there is no interaction.

Results

Behavior

- Median tail **AoA** and **spread angle** are **not** significantly different between the **presence** and **absence** of **competitors** (Fig. 1&2).
- However, non-linear mixed effects for repeated measures showed **interactions** between **change in velocity** and **presence of other birds** for tail **spread angle** ($p=0.02$)(Fig. 2).

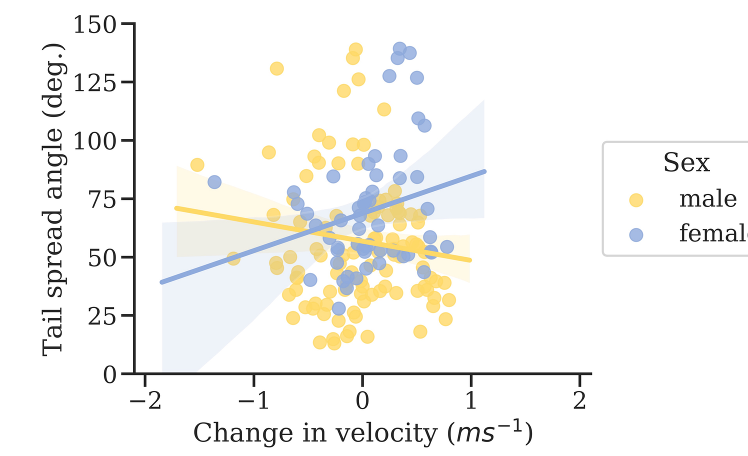


Figure 3. Median tail spread angle across changes in velocity by sex of American Goldfinches.

- There is no significant difference between **sexes** for tail **spread angle** and **area** (Fig. 3& S1).
- There are significant interaction effects between **sex** and **change in velocity** for tail **spread angle** ($p=0.04$)(Fig. 3).

Aerodynamic forces

- Median tail **AoA** ($p<0.01$) and **spread angle** ($p<0.01$) were significantly different across change in velocity (Fig. 1&2).
- There are no significant differences between **species** for tail **AoA** and **spread angle** (Fig. S2).
- There are no significant differences in tail **area** for change in velocity or presence of other birds (Fig. S3).

Discussion

- Interaction effects between **spread angle** and tail **AoA** and the presence of competitors could support two hypotheses:
  1. The **behavior hypothesis** would be supported if the birds are **flashing** their tail to **signal** a competitor, which would change their velocity.
  2. Or, the **aerodynamic hypothesis** could be supported if they are decelerating more in the presence of **competitors** and use their tail to **induce drag**.
- The **lack of variation** between goldfinch **sexes** when not interacting, and among other studied **species**, suggest that tail kinematics primarily function **aerodynamically** in slow flight.
- Our current analyses are unable to address the role of the tail in non-linear maneuverability.

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