Wing Ecomorphology Lab

- **Motivation:** Trade-offs in Body Design / Ecology
- **Implication:** Degree of use of wings under water has a "drastic" effect on flight adaptation

A Variety of Fliers

A Variety of Divers
Four Basic Types of Wings

The form of a bird's wing is so basically important to the successful exploitation of an ecological niche that it inevitably yields many instructive examples of adaptive evolution.

It also provides interesting examples of convergence, as is to be expected of a structure that contributes materially to such important functions as locomotion and the obtaining of food.

Savile (1957) classified wings into 4 main types:

- Elliptical
- High Speed
- High aspect-ratio
- Slotted high-lift
Four Basic Types of Wings

- **Albatross**: Slow gliding / soaring
  - High aspect ratio
  - Pointed wing tips

- **Falcon**: High speed flight
  - Pointed long wings

- **Eagle**: Gliding
  - Low aspect ratio
  - Slotted wings

- **Crow**: Agile flight
Basic Wing Types - High Aspect Ratio

Actively-soaring species: albatrosses, petrels and gulls

long and narrow (some albatrosses can have aspect ratio as high as 18)

High aspect ratio, with no slotting

For high-speed flight and dynamic soaring; found in soaring seabirds;

Long and cumbersome

difficult to take off

designed for soaring long distance flight with little effort

www.natureskills.com/birds/bird-wings/
Basic Wing Types - High Speed

Found in open-habitat birds, long-distance migrants and birds that feed in flight (hummingbirds);

have moderate to high aspect ratio,

low camber

slender tips and no slotting

Built for speed

Require a lot of work to keep the bird airborne

www.natureskills.com/birds/bird-wings/
Basic Wing Types - Slotted

Passively-soaring Species: hawks, eagles, swans and geese

Provides extra lift is needed to keep their large bodies airborne or to carry heavy prey

Have moderate aspect ratio

Deep camber

High slotting

Notice extreme notching present on leading primary feathers (far left)

Adaptation called emargination

www.natureskills.com/birds/bird-wings/
Basic Wing Types - Elliptical

Found on birds that live in habitats with dense vegetation

Short. With low aspect ratio.

Adapted for good maneuverability.

High degree of slotting - associated with requirement of slow speed flight.

Use high beat frequency, for rapid take-off, acceleration and turning

Shape creates uniform pressure distribution over the wing

www.natureskills.com/birds/bird-wings/
Wing Design Features

**Length:** The longer the length of the wing, the higher the lift.

Air wraps around the wings and leads to an “inactive” area on the tips... and also causes drag on the wing.

Longer wings have a disproportionately larger “active” area - which provides lift - relative to the “inactive” areas.
**Wing Design Features**

**Design:** The alula and Slotting

**Alula ("winglet"):**
Freely moving first digit (thumb); bears 3 to 5 small flight feathers

The alula is held flush against the wing; but it can be moved. When flying at slow speeds or landing, bird moves alula upwards and forwards, which creates a slot on the wing's leading edge.

This gives wing a higher angle of attack - lift - without stalling.
Describing the Seabird Wing

Describe any bird wing using a few generalizations

- Wing length (span)
- Wing width (chord)
- Wing shape (aspect ratio): length / width
- Wing Loading: Body Size (Mass) / Wing Size (Area)
Flight Energetics - Wing Loading

Wing Loading: Body Mass / Wing Surface Area

What does this mean?

The loaded weight of the bird divided by the area of the wings.

Implications:

The faster an aircraft (bird) flies, the more lift is produced by each unit area of wing. Thus, with higher speed: a smaller wing can carry the same weight, operating at a higher wing loading.

Correspondingly, the take-off speeds will need to be higher.

The higher the wing loading, the lower the flight maneuverability.
Flight Energetics - Wing Shape

Aspect Ratio: Wing Length / Wing Width

What does this mean?

The ratio describes the wing shape - dimensionless number

Implications:

Long and skinny wings get more lift. Are harder to flap faster.

Short and stubby wings get less lift. Are easier to flap faster.

Shorter wings are more maneuverable in the air and under water.
Flight Energetics - Wing Shape

(Norberg 1988)
Locomotion Costs: Flight


Flight Computer Software

(Pennycuick 2008)

Google Book Link
Energetic Costs of Flight

Describing wing shapes with standardized measurements:

Wing span: length (cm)
Wing chord: width (cm)

Mean chord:

\[ c_m = \frac{S_{wing}}{B}. \]  

The chord of a particular wing, unlike its span, does not have a unique value unless the wing is rectangular, which is unusual. Most wings have a maximum *root chord* where the wing joins on to the body, and taper to a smaller *tip chord*, with the chord diminishing along the span. A few flying animals (butterflies) have negative taper, meaning that the tip chord is greater than the root chord. The *mean chord* \((c_m)\), which does have a unique value for the wing, is the ratio of the wing area \((S_{wing})\) to the wing span \((B)\):

\[ c_m = \frac{S_{wing}}{B}. \]  

(Pennycuick 2008)
Wing Loading Patterns

**Aspect ratio**
The aspect ratio ($R_a$) is the ratio of the wing span to the mean chord, and it expresses the shape of the wing:

$$R_a = \frac{B}{c_m}, \quad (2)$$

or, more conveniently:

$$R_a = \frac{B^2}{S_{wing}}. \quad (3)$$

Aspect Ratio (first calculation):  Length / Mean Chord

Aspect Ratio (second calculation):  Length ^2 / Area
Wing Area and Tail Area

**Tail area**
The tail is an accessory lifting surface in birds, and is more analogous in its function to a flap than to the horizontal tail of conventional aircraft. Birds’ tails have been represented as an expandable delta wing, behind the main wing (Thomas, 1993). This is not included in *Flight* as most birds only deploy and use their tails at low speeds that are below the range covered by the calculations, and besides, the theory is somewhat conjectural. The tail is usually furled at normal cruising speeds, from the minimum power speed up, and may then be assumed to contribute no lift.

Wing area is somewhat troublesome to measure (Box 1.4) and not as critical as wing span. If a few wing areas are measured among a sample of birds of the same species, they can be used to get an estimate of the aspect ratio, which may be assumed to be constant for the species. This means that the wings are assumed to be all of the same shape, though not necessarily the same size. Then, if a bird’s span has been measured, the aspect ratio can be used to estimate its area by inverting Equation 3:

\[ S_{\text{wing}} = \frac{B^2}{R_a}. \]  

*Flight* will accept either the wing area or the aspect ratio for input. If supplied with one, it will calculate and enter the other automatically, so long as the wing span has already been supplied.
Wing Area Measurement

Semi-span: from the tip of the wing to where the wing connects with the body.

Root chord: wing width where it connects with the body.

Root box: rectangular area of the body, in between the two wings.
1. Check out your bird

- Where are the feet placed on the body? Measure L
  
  Write a brief description and make a drawing

- What are the feet like?
  
  Write a brief description and make a drawing

- What is the tarsus like?
  
  Write a brief description of the cross-section shape
  (Note: use calipers to measure tarsus cross-section)


Parallel to leg movement
Perpendicular to leg movement
2. Make Bird Measurements

- Weight (to the closest gram):
  
  Use hand-held scale (for big birds) or table top

- Lay out bird on its back and stretch the wings out.
  
  Hold the bird down and make a tracing of both wings.

Get the contour of the feathers and make sure you mark the Root Chord (where body and winds meet).

Measure span (wing length) to closest mm with a ruler.

Write Bird ID, mass (g) and span (mm) in the tracing.
2. Make Wing Measurements

Wing surface area = Wingspan × mean chord length = 5920 cm²
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Wing surface area = Wingspan × mean chord length = 5920 cm²

Mass = 7960 g
Wingspan = 310 cm
Mean chord length = \( \frac{16 \text{ cm} + 19 \text{ cm} + 22 \text{ cm}}{3} = 19 \text{ cm} \)

Aspect ratio = \( \frac{\text{Wingspan}}{\text{Mean chord length}} = \frac{310 \text{ cm}}{19 \text{ cm}} = 16.32 \)

Wing loading = \( \frac{\text{Mass} \times \text{acceleration}}{\text{Wing surface area}} = \frac{7960 \text{ g} \times 9.81 \text{ m/s}^2}{5990 \text{ cm}^2} = 13.26 \text{ N/cm}^2 \)

NOTE: We will not measure the mean chord length, but will calculate it using the area / wingspan ratio
3. Quantify the Wing Area

- Cut the wing tracing, so the paper is at right angles.
- Measure length / width of rectangle, to closest mm.
- Weigh the paper using table top scale (0.1 g resolution)
- Cut the wing tracing (carefully, with scissors) and weight it with table top scale (0.1 g resolution)
- Record all data into your bird data sheet
Show and Tell - Oct 11th

Enter your data in my laptop before you leave.
I will send you everybody’s results for analysis.
Bring back your write up / results next week.
References


