A STUDY ON WING MORPHOLOGY OF AVIFAUNA COMMUNITY

Izwan Asraf Md Zin

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IZWAN ASRAF MD ZIN

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DECLARATION

I here declare that the work in the thesis is my own except for quotations and summaries, which have been duly acknowledged.

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IZWAN ASRAF B MD ZIN
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A Study on Wing Morphology of Avifauna Community

Izwan Asraf Md Zin

Animal Resource Science and Management
Department of Zoology
Faculty of Resource Science and Technology
Universiti Malaysia Sarawak

ABSTRACT

Wing loading and aspect ratio are important in determining the ecological adaptation of avifauna community. Wing loading determines the power needed to fly while aspect ratio determines the agility and manoeuvrability of the birds. This study was conducted in Bako National Park and Kubah National Park. A total of 249 birds representing 17 families were analysed and there are significance differences between aspect ratio and wing loading among the families. From this study, it can be concluded that birds that have high wing loading value are often found in open habitat. While, birds that have low wing loading value are often found in denser habitat. Birds that have rounded wings usually have long aspect ratio. While birds that have long and slender wings have higher aspect ratio. These are the characteristics that are useful in determining the habitat of a birds. However, many other aspects should be considered in understanding the wing morphology of the birds.

Key words: Wing loading, aspect ratio, manoeuvrability, agility, community ecology.


Kata kunci: Muatan sayap, nisbah ruang permukaan sayap, pergerakan burung, ekologi komuniti.
1.0 Introduction

Birds can be defined as animals possessing only one condyle, a single bone in the middle ear, front limb modified for flight and body covered with feathers (Orr, 1961). They consist of 27 living orders and approximately 9672 species all over the world. According to King et al. (1991), 1198 species of birds are recorded in Burma, Malaysia, Indochina and Hong Kong and 622 birds’ species from Borneo (Smythies, 1999).

Birds consist of two subclasses which are Archaeornithes and Neornithes. Archaeornithes can be defined as extinct birds possessing teeth in both jaws and long feathered tail, three claws and vertebrae are divided to sacrum and amphicoelous. While Neornithes or true birds can be defined as extinct and living birds with developed sternum that usually possesses a keel, tail and vertebrae amphicoelous or heterocoelus (Orr, 1961).

Flight is the central avian adaptation where they have evolved a wide range of specialised modes in flying. Birds can fly in varieties ways; hover in one place, dive speed and fly upside-down and backward (Gill, 1990). Thus, understanding the aerodynamic principles is vital in order to study their flight.

Wing loading is important as it determines the speed and power needed for flying (Carrascal and Polo, 2005). For that reason, it is important for some species of shorebird as it provides quick take off to escape from predator by having rounded wing tips (Burns and Ydenberg, 2002; Burns, 2003). Birds that have high wing loading such as grebes, loons and flamingo have to flap and skitter over the water to gain enough lift for flight (Swaddle et al., 2003). While duck such as mallards that have low wing loading and more lift per wing beat, enables them to take off vertically without skittering start. However, birds’ would have decreased
acceleration performance when they have low wing loading and high aspect ratio (Warrick et al., 2002) Black vultures, which have high wing loading and rounder wings usually, wait for the assistance of rising warm-air currents (Gill, 1990).

Birds will have lower chances of encountering food while foraging if they decrease the flying time. However, increasing the flying time would also increase the rates of exposing the birds to their predators (Carrascal and Polo, 2005). Thus acquiring height in early escape from predators is vital for the birds (Kullberg et al., 2000; Burns and Ydenberg, 2002; Swaddle et al., 2003; Renner, 2006). Hence, species evolved to enhance escape ability to reduce predation risk during foraging (Burns and Ydenberg, 2002; Williams and Swaddle, 2003; Dial et al., 2006). Interspecific flight dynamic theory assumes that large birds have less power output available than smaller birds (Burns and Ydenberg, 2002).

Migratory birds possessed pointed wings to reduce drag while flying. However, it would reduce the take off performance of the birds themselves (Burns, 2003). They also usually consume more food as fat storage which provides energy for migration. Moreover, increasing the body weight would increase in wing load and flight performance (Carrascal and Polo, 2005; Kullberg et al., 2005). However increasing body mass will raise the risk of predation (Kullberg et al., 2000; Burns and Ydenberg, 2002). Empirical studies showed that the increase in wing load during migration would cause the evasive ability to be less effective (Kullberg et al., 2005).

Increasing of body mass is proportional to the size of birds indicating allometric pattern (growth of body parts at different rates) of growth (Carrascal and Polo, 2005). Factors that affect flight ability and escape flight include foraging techniques, sexual flight display,
migration and predation risk (Burns, 2003; Swaddle et al., 2003; Macleod, 2006). However, mass is said to have no measurable effect on the ability to take off (Kullberg et al., 2005; Macleod, 2006; Renner, 2006).

1.1 Justification

Biologist studying on the eco-morphology of the bird is intended to know how its body structure has evolved and assisting in flying. However, most of these studies were conducted mostly in Europe where people would study migratory birds (Burns and Ydenberg, 2002; Burns, 2003; Peiro, 2003). In this study, migratory birds are found to have long and slender wings to assist in long distant flying.

This study was the first attempt to understand on the role of wing morphology in relation to habitat types of selected birds in Sarawak.
1.2 Objectives

1. To provide information regarding the wing morphology of avian fauna found in Bako National Park and Kubah National Park.

2. To compare if there is significance difference of wing loading and aspect ratio among selected families of birds.

1.3 Hypotheses

$H_0$ There is no significant difference in wing loading of birds from different families.

$H_1$ There is significant difference in wing loading of birds from different families.

$H_0$ There is no significant difference in aspect ratio of birds from different families.

$H_1$ There is significant difference in aspect ratio of birds from different families.
2.0 Literature Review

2.1 Wing Shape and Sizes

The shapes of wings are vital in affecting the flight abilities. The speed, agility and energy used during the flight depends on the shape and size of the wings. Lift and drag produced in flying mostly depends on the wing dimensions and flowing of the air to the wing. Gill (1990) describes four types of wing shape that useful to describe the environment of the birds (Figure 1).

![Variations of birds' wing shape](Source: Gill, 1990)

(A) Long, narrow wings of high aspect ratio such as albatross.
(B) Short rounded wings of low aspect ratio such as grouse to provide faster take off and rapid maneuvers.
(C) The slim, unslotted wing of falcons provides fast, efficient flight in open habitat.
(D) Slot increase lift and gliding ability such as buteo.

Fig. 1: Variations of birds' wing shape (Source: Gill, 1990).
The theory of aerodynamic performance is usually influenced by the shape of wingtip. According to Swaddle et al. (2003), changes in wingtip shape will influence low speed flight in European Starling (*Sturnus vulgaris*) where they have rounder wingtip in order to enable faster take-off which is vital in escaping from predator. Rounder wingtip in *Phylloscopus* warblers assist in steeper angle of take off compared to more pointed wingtip of *S. vulgaris*. Thus, adaptations to different selection pressures such as migration, sexual selection and habitat may influence changes in wing shape and wingtip.

A study on *Calidris* sandpiper by Burns (2003) in Columbia showed there was no correlation between wing pointedness and migration distances. However, there was positive correlation between wing pointedness and relative fuel load. Size of the birds did not show any positive correlation with either migration distance or wing shape but positive correlation occurred with relative fuel load.

A study conducted by Blem (1975) on House sparrow (*Passer domesticus*) in North America showed that there was significant a difference in wing loading between sexes. Female sparrows showed greater wing load. No consistent geographic variation in wing area or wing cord were seen in both sexes. However, differences in latitudinal affect the wing load in both sexes.

In a study conducted by Carrascal and Polo (2005) in Madrid, Spain on the changes of birds' body mass in wild birds showed that there was significant effect towards the birds during the time of day and midday temperature. There was positive change of the birds during time of the day and negative changes during midday temperature. Furthermore, the decreasing in body mass after reduction of wing area correlated with the tarsus length. The study also
indicated that the reduction of wing area affected the flying and feeding frequency. In other words, birds' mass will change according to their environment condition (Carrascal and Polo, 2005; Macleod and Gosler, 2006).

A study conducted by Hedenstrom (1998a) in Sweden showed that there is significant difference on the wing area and wing raggedness. Thus, the reduction of wing area and wing span due to the reduced remiges would mostly cause cost of the flight to increase. This happened to the long distance species. Thus, species which involved in over water flight such as *Phylloscopus trochilus* (Willow warbler) are those that have high aspect ratio that decrease the cost of powered flight. Therefore, lift distribution and flight performance are affected by the gaps in the wings.

According to Hedenstrom (1998b) on study over Ross's Gull (*Rhodostethia rosea*) and Sabine's Gull (*Larus sabini*) in Taymyr, flight speed in birds determined by ecological environment and morphology (body mass, wing area and wing span). A study of the species during their breeding and foraging activity indicated both species are similar due to similarity in wing morphology. By measuring both species flight speed, it can be suggested that the different characteristics in flight speed is an adaptation to ecological situation. Sabine's Gull modified their airspeed in relation to headwind and tailwinds which also support the aerodynamic theory. Flying into a headwind will provide greater airspeed while flying into a tailwind will decrease the airspeed.

In a study conducted by Peiro (2003) in Spain, variation of wing shape with different age within species Reed warbler (*Acrocephalus scirpaceus*) indicated that adult have more wing length and elongated wing shape which has higher convexity and rounded. This could be
related to morphologic adaptations within population which can also be related to breeding
behaviour and migration distance. Juvenile birds’ trapped in the passage possessed more
pointed wings that those trapped in breeding period. While adults’ birds’ possessed more
rounded wings which were caught during migration period compared to those trapped in
passage. Therefore, it is suggested that the interspecific differences in wing shape were
caused by the differentiation of migration pattern of the population of *A. scirpaceus*.
Moreover, this age related variations are the effects of trade off between cost of predation
which favour shorter and rounded wings to provide greater manoeuvrability in juveniles.
High manoeuvrability decreased the flight speed and less power to take off. Hence, adults of
*A. scirpaceus* possessed more pointed wings due to migratory cost that provides greater speed
and less energetic waste in long distance flight (Mulvihill and Chandler, 1991; Peiro 2003).
These temporal variations in wing length and degree on convexity of wing shape and wing tip
are usually related to migration distance in many passerines (Peiro, 2003; Nebel, 2005).

In another study by Burns and Ydenberg (2002), there are no significant differences of
gender and wing loading between Least sandpiper (*Calidris minutilla*) and Western sandpiper
(*Calidris mauri*) in a control environment. Least sandpiper has better acceleration at early and
late stage while Western sandpiper has greater angle in escaping. This can be explained by
the physical attributes of Western sandpiper that have shorter primary feathers than Least
sandpipers. The negative effect of performance was caused by the migratory fuel which
affects the escape flight within the species (Peiro, 2003). Increased wing loading would lead
to the decreases the escape speed in Least sandpiper and Western sandpiper. However, the
flight performance was increases if the wing loading is increases.
In a study conducted by Macleod (2006) on great tits (*Parus major*) in a control environment, the substitution between avoiding predators and gaining energy plays vital role in the bird’s life. Birds that consume more food as fat storage will reduce the risk of starvation but increases the predation risk. Migratory birds’ fuel loading will decrease the angle of ascent escape and reduce the flight speed. However, there was no significant change occurred in flight performance with the diurnal mass change. This result was caused by three possibilities, namely, the escape flight of *P. major* may not be at maximum level as they seek for optimum energy level to avoid chances of injury and provide better manoeuvrability. Second, it is believed that greater power was generated by the muscle during the day to compensate for increased mass. Finally, the reduced of flight performance might be very small to be detected.

Many birds utilise flight extensively for foraging for food sources (Rayner 1982). Therefore, the birds’ flying strategies are closely interrelated with the ecological character of the habitat along with the birds’ physiological and ecological requirements (Rayner, 1982). According to Smythies (1999), there are many morphological distinctions between closely related species. For example, Gray-breasted Babbler and Moustached Babbler have rounded wings which reflects the manoeuvrability in flight, but differ in wing:tail and wing:tarsus ratio. Moreover, body size and shape are also important in determining the foraging position or habit. Chestnut-capped Laughingtrush and Sunda Laughingtrush are often seen to feed together. However, the Sunda Laughingtrush have slightly larger wing span and body that Sunda Laughingtrush and spends more time on the ground compares to Sunda Laughingtrush. This study would show the general idea of the avifauna wing morphology adaptation to their environment. Moreover, closely related species tend to occupy the same habitats (Forstmeier *et al.*, 2001)
3.0 Materials and Methods

3.1 Study site

The first study area lies in Bako National Park, Kuching (Bukit Gondol, N 01° 42.07', E 110° 28.30', 233 m above sea level) (Hazebroek and Abang Kashim, 2000). This study was conducted from 28 August 2006 until 1 September 2006. Two sites were included during four days sampling, there were Bukit Gondol and Paya Pelutong. Bukit gondol which is approximately 260 m above sea level consists of mixed dipterocarp forest (Hazebroek and Abang Kashim, 2000). This area is dominated by plants from family Aracaceae and some other plants such as kapor (*Dryobalanops aromatic*) and rhu (*Cassuarina littoria*). The light inside the study area appears to be much brighter than in the mixed dipterocarp forest, which has a much more complex structure and denser canopy. Where the soils are even poorer and less able to retain moisture, the forest is shorter and denser and the tress is usually thin and straight. The vegetation can be described with average 2.5 poles, 3.5 saplings, 0.9 trees and 2.4 seedlings with 66% canopy cover based on ten observations with 1 x 1 m quadrate. This shows that the forest is currently undergoes a change to a complete mixed dipterocarp forest which has denser canopy cover with a relatively few plants on the floor.

The second study site is Kubah National Park located 20 km from Kuching, with the coordinates N 01° 36' 44.2' and E 110° 11' 31.7' (Hazebroek and Abang Kashim, 2000). Kubah National Park is of flora and fauna. It is 2230 ha² wide and consists of mixed dipterocarp forest and lower montane forest (Hazebroek and Abang Kashim, 2000). This area is considered as one of the richest palm site in Sarawak. Some of the species that can be found in Kubah National Park are fan palm (*Licuala orbiculari*), climbing palm...
(Daemonorops formicaria) and graceful palm (Pinanga salicifolia). Trapping were done in lower elevation (250 m - 500 m) and upper elevation (500 m - 750 m).

3.2 Field Methodology

Mist nets that were used were 25 mm mesh, 9 m long and 4 m high. Ten mist nets were deployed at the identified areas, five nets at ground level and another five nets were placed at sub canopy level which is approximately 20 m high. The bottom of mist nets were the ground to prevent birds from escaping by hopping, running or run under it (Bub, 1991). Hence, locations of deployed mist nets were determined using Global Positioning System (GPS). Mist nets at sub canopy level (10-15 meters) were placed between two trees. Mist nets were placed for three days at one location and shifted to a new place to reduce recapture and increase catchability. According to Bub (1991), mist nets work best in narrow alley and in shade cast by trees. The mist nets were checked every hour starting from 0700 until 1800. The nets have to be checked frequently in order to prevent the birds from dying. Birds' measurements were recorded in a standard form. Birds’ wing area were traced by drawing the wing on A4 size graph paper (in millimetre scale) and the body were weighed using Pesola spring balance with 50 g, 100 g and 500 g capacity. The individuals were identified using Smythies (1999) and Robson (2005). The birds were sexed and ringed on the right leg before being release at the captured site.
According to Pennycuick (1989), wing area can be defined as the projected part of fully spreaded wings including the area of that part of the body that is included between the wing roots. This area was measured in order to obtain the value of wing loading and aspect ratio (Fig 2).
3.3 Statistical Analysis

Birds' wing loadings determine the power needed for flying (Carrascal and Polo, 2005) and gliding calculation of a bird (Pennycuick, 1989). Lower wing loading indicates that the bird fly slower and more manoeuvrable than those with higher wing loading. The cost of flight is measured by the relation of total wing area and body mass which is how many grams of bird each unit area of wing has to carry. Thus, it was determined by the formula following Pennycuick (1989);

Wing loading (WL) = \( \frac{w}{A} \)

Where; \( w = \) weight (kg)

\( A = \) wing area (m²)

Before proceeding with the wing loading calculations, the weights of the birds were converted to mass using the formula (assuming the standard earth gravity is 9.81 m s⁻²) to follow SI system;

\( 1 \text{ kg} \times 9.81 \text{ m s}^{-2} = 9.81 \text{ kg m s}^{-2} (\text{N}) \)
Aspect ratio is a measurement of the shape of a wing. It is the ratio of the wing span to the mean chord (Pennycuick, 1989). Aspect ratio is used to determine the control performance of the birds captured. The higher the aspect ratio, the lower drag produced by the wing at a given speed. Wing aspect ratio was calculated with the formula as;

$$\text{Aspect ratio (AR)} = \frac{B^2}{S}$$

Where; $B =$ wing span (m²)  
$S =$ surface area of wing (m)

Kruskal-Wallis nonparametric test were used to determine if there is significant different between wing loading and aspect ratio based on every families respectively. This test was used to determine the equality of median among the families with the assumptions;

1. All data must be selected from random populations.
2. The data must be not normal (heteroscedasticity).
3. All individuals must have equal chance of being selected.
4.0 Results

A total number of 249 individuals representing 17 families and 55 species were measured and analysed accordingly. Due to lack of numbers for a genus or species, the table are pooled into families (Table I).

Table 1 shows the mean wing loading and aspect ratio of pooled data for each families. The highest mean value for wing loading is from the family Columbidae (43.85) followed by Falconidae (33.61) and Halcyonidae (32.70). The lowest mean value for wing loading is from the family Estrildidae (8.92). Highest aspect ratio mean value is from the family Strigidae (7.81) followed by Falconidae (7.26), Columbidae (4.82) and Timaliidae (4.82). While the lowest mean value for aspect ratio is from the family of Corvidae (1.27).

Table 1: Standard error of mean, standard deviation, range and mean measurements of wing loading and aspect ratio based on families. Full list of the species are listed in Appendix 1.
na indicates that data is not available due to only one sample available.

Kruskal-Wallis nonparametric test showed that there are significance difference on wing loading (H = 116.41, df = 16, p = 0.000) and aspect ratio (H = 47.44, Df = 16, p = 0.000).

Table 2 showed on the categorization aspect ratio and wing loading based on the mean values. The values are categorised into three categories which are high, medium and low. Wing loading mean range between 0.01 to 19.99 is considered as low, 20.00 to 29.99 is considered as medium and 30.00 to 49.99 is considered as high. While for aspect ratio, mean value range from 0.01-3.99 is considered as low, 4.00-6.99 is considered as medium and 7.00-9.99 is considered as high. These categories just confined for this paper to simplify our understanding.

In general, high wing loading value describes species that occupy in the open area and have long wings. This is due to high wing-loading explains high flight speed with poor maneuverability. They usually use sit and wait in order to hunt for their prey. Light wing loading values (low and medium) describes species that occupies dense vegetation. They mainly consist of active foragers and also characteristics of sit and wait hunting mode (Gamauf et al., 1998). Whereas, high aspect-ratio indicates long and narrow wing shape and poor agility (Findley et al., 1972; Mackenzie et al., 1995; Hodgkison et al., 2004). Low aspect ratio corresponds with short, broad wings and less efficient flight (Jones et al., 2003)