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On aerial drumming by snipes
Takeshi SUGIMOTO, Kanagawa University

ABSTRACT
Snipes are known to exhibit peculiar display flights. They generate sounds by flattering outer tail feathers as they dive. Most snipes are almost identical. But one can tell them in the hand, because the number of tail feathers differs among species. This means the sound made by tail feathers also differs among species. This study treats Latham’s Snipe Gallinago hardwickii. Measurements and analysis reveals the geometry and configuration of outer tail feathers accounts for the feature in sound spectrum of their aerial drumming.

Keywords: Aeolian tones, Aerial display, Biofluidodynamics

1. Introduction
Vocal communication is very important for birds. Most birds make most of their tracheas and sing special songs in the beginning of mating season. Common Snipe and its kin, genus Gallinago, do sing songs as well as exhibit peculiar display flights called aerial drumming. They generate sounds by flattering outer tail feathers as they dive. Snipe species are extremely similar to one another, and field identification is almost impossible. But one can tell them in the hand, because the number of their tail feathers differs from species to species. This means aerial drumming sounds also differ from species to species. Common Snipe G. gallinago bleats by using tail feathers. Latham’s Snipe G. hardwickii roars by tail feathers, so it is locally called thunder snipe.

This study offers physical explanation of Latham’s Snipe’s aerial drumming sound by measuring geometry of tail feathers and analyzing sound spectrum. Comparison of four species occurring in Japan is also made to reveal the difference of their tail feathers and sounds.

2. Measurements
2.1. Geometry of tail feathers
A specimen, which was lent me by the Wild Birds Society of Japan, is examined. This bird was found dead in Okinawa on September 9 1989. It is now mummified, so its weight, 53 g, and wing length, 142 mm, mean nothing. The ornithologically important figures are as follows: total length 265 mm, bill length 65 mm, and tarsus 37 mm. Its plumage tells this is a juvenile.

The most important thing is information on tail feathers. Figure 1 shows the broader inner feathers to the left and the thinner outer feathers to the right. The outer three feathers are used to make sounds as shown in Figure 2. The outermost feather looks like the crescent moon and has only 3 mm width near its tip and sweepback as large as 45 degrees. The next feather is 4 mm wide near its tip and its sweepback angle varies from zero to 30 degrees toward its tip. The third outermost feather is 5 mm wide near its tip and its sweepback angle varies from zero to 20 degrees toward its tip.

Fig. 1. Tail feathers on the left side of Latham’s Snipe

Fig. 2. Silhouette of diving Latham’s Snipe

2.2. Sound spectrum
Several sound records were examined and Ueda’s was found the best. Even the best is recorded in the field, so there exist ample background noises. Therefore it is important to identify a subtle clue of thundering sound among background. The Sony-Tectronics Real Time Spectrum Analyzer can provide a series of very short-term spectra, and it was found useful. To see moving spectra and hear the sound at the same time one can identify which peak or plateau corresponds to the thundering sound of aerial drumming. Figure 3 shows a typical result of the analysis. A hill-like part of the spectrum around 800 Hz corresponds to the thunder. Doppler effect may exist, but the recording conditions are unknown.

Fig. 3. Typical sound spectrum of aerial drumming (0 to -100dB in 1kHz span)
3. Discussion

3.1. Annotation as Aeolian tones

Let us estimate the frequency of Aeolian tone that outer tail feathers may generate. The upper bound of flight speed corresponds to the terminal velocity of dive. Equating the gravity force with the aerodynamic drag one has the relation:

\[ mg = \frac{1}{2} \rho V^2 C_D. \]  

(1)

Common Snipe has such values as follows\(^2\): \( m \) is 98 g; \( S \) is 0.042 m\(^2\). Using the typical values 1.025 kg/m\(^3\) and 0.05 for \( \rho \) and \( C_D \) respectively, one reaches the conclusion that the terminal velocity is 30 m/s. A bird can attain the terminal velocity by falling down 44 m.

Table 1 summarizes data related to outer tail feathers of four \( G. \) species observed occasionally at the same time in Japan. From an aerodynamic point of view outer tail feathers of \( G. \) gallinago and \( G. \) hardwickii can be treated as flat plates, while very thin outer tail feathers of \( G. \) megala and \( G. \) stenura are equivalent to circular cylinders. Their Strohal numbers correspond to those of a flat plate and a circular cylinder. The definition of Strohal number states

\[ St = \frac{c f}{V}, \]  

(2)

where \( c \) denotes the chord length. Frequencies estimated by the relation above are also tabulated in the bottom row of Table 1. As for \( G. \) hardwickii the estimation agrees well with the feature found in the sound recorded in the field.

Table 1. Outer tail feathers of four \( G. \) species

<table>
<thead>
<tr>
<th></th>
<th>( G. ) gallinago</th>
<th>( G. ) hardwickii</th>
<th>( G. ) megala</th>
<th>( G. ) stenura</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. (pairs)</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>( c (\text{mm}) )</td>
<td>0.15</td>
<td>0.15</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>( f (\text{Hz}) )</td>
<td>500</td>
<td>750</td>
<td>2000</td>
<td>4000</td>
</tr>
</tbody>
</table>

3.2. Interaction of sounds

Outer tail feathers are different in size as well as their number. Frequencies are dependent on chord length, but why the total number differs among species?

Figure 4 shows the reproduced configuration of outer three feathers under the following condition: 9 feathers are supposed to be spread out to form a 90 degrees sector; thus the angle between two adjacent feathers is ten degrees each. In this configuration the maximum distance between the outermost and the second outermost feathers is five times larger than the chord length of the outermost feather; the maximum distance between the second outermost and the third outermost feathers is four times larger than the chord length of the second outermost feather.

Interaction of three feathers will enhance the strength of the drumming sound, if the following situation may occur: a sound source, left the upstream feather, travels such a distance that this source eventually meets with the next source just leaving the downstream feather. Let \( L \) and \( U \) be the traveling distance and moving speed of a sound source, and \( f_r \) the arriving frequency of sound sources at the downstream feather, is given by

\[ f_r = \frac{U}{L}. \]  

(3)

Excitation occurs, if \( f_r \) coincides with \( f \). In that case equations (2) and (3) yield the relation:

\[ L = \frac{U}{f_r c}. \]  

(4)

If we adopt 0.8 for \( U/V \), then equation (4) constitutes the relation: \( L = 5.3c \). This is roughly true to the configuration shown in Fig.4.

The thinner outer tail feathers become, the larger the number of modified tail feathers becomes as shown in Table 1. To make higher frequency sound louder many tail feathers are presumably necessary.

4. Conclusions

I have measured geometry of \( G. \) hardwickii's tail feathers and analyzed the sound spectrum of their aerial drumming recorded in the field.

The frequency of aerial drumming, estimated by use of geometric data and Aeolian tone theory, shows fare agreement with the feature found in the sound spectrum.

It was also found that four \( G. \) species occurring together in Japan have distinctive particular frequencies of aerial drumming.

The number of outer tail feathers becomes larger as the frequency of aerial drumming gets higher. Sound is excited by interaction of upstream and downstream sound sources. Higher frequency sound has usually small amount of energy, but will be enhanced by resonance of multiple tail feathers.

Laboratory experiment is necessary to examine more detail about the physics of aerial drumming.

Acknowledgement

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Reference

2) Tennekes, H.: The simple science of flight, the MIT press (1996)