Higher video frame rate is necessary for recording flash pattern of Luciolinae fireflies

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ABSTRACT

Light display of flying males of three species of Luciolinae firefly were recorded by long exposure photography and by video cameras operating at different frame rates, ranging from 25 frames per second to 100 frames per second. The video clips were imported into TiLIA - a software package for image analysis of firefly flash patterns. Graphs showing flash patterns exported by the software are compared, with reference to the respective long exposure photos. It is found that higher frame rate produce better representation of firefly flash patterns and video recording at 25 frames per second or 50 frames per second produces inaccurate and false results.

Key words: Luciolinae, flash patterns, video frame rate

INTRODUCTION

Being the largest sub-family of the firefly family Lampyridae, Luciolinae contains more than 400 known species. The group is called flashing fireflies. So far all the known light display by Luciolinae fireflies are in the form of flashing in contrast to continuous glow shown in some other sub-families.

Flash pattern varies amongst different Luciolinae firefly species, ranging from simple pulsation to composite flash pattern or flash train (Yiu, 2012; Ballantyne et al., 2013; Fu, 2014). Simple pulsation flash patterns are distinguished by two parameters – pulse duration and inter-pulse duration; sometimes it is described as pulse frequency. Composite flash patterns are distinguished by a number of parameters – flash duration, inter-flash duration, number of pulses per flash, pulse duration, inter-pulse duration; sometimes a flash consists of pulses with significantly different amplitude.

Long exposure photography is a simple method to show a rough picture of the flash pattern, without temporal information. To have a graphical representation of the flash pattern, containing temporal details, video recording is necessary. The recorded video is analyzed using a computer software showing the changes of flash intensity against time.

No matter it is in physical film format or in digital format, a video is made of a sequence of images. For the purpose of showing ordinary moving objects or motions smoothly. The rate of recording or displaying is at a rate of 25 images per second or faster. This is called the video frame rate – fps (frames per second). Most commonly used frame rates for video recorders in the market are 25fps, 30fps, 50fps, 60fps. Some high grade video recording devices and devices for recording sport actions provide option of 100fps or higher.

To effectively capture the particulars of a fast moving object, higher frame rates for recording will be adopted. The videos recorded at high frame rates can be displayed or played back at lower frame rate in order to reveal the details of the fast motion. For example, a video recorded at 100 fps can be played back at 25 fps.

Default frame rate of most video recording devices in the market is 25fps or 30fps. If the flash/pulse frequency of a firefly is equal or higher than the video frame rate - ≥ 30 hertz, what would happen? Would a higher frame rate reveal more details of the flash patterns?

MATERIALS & METHODS

Videos of flying male *Pteroptyx maipo* displaying light signals were taken by a Sony Alpha 7S digital camera, video recording frame rate were set as 25 fps, 50fps and 100 fps respectively.

Videos of flying male *Curtos fulvocapitalis* displaying light signals were taken by a Canon EOS 5D Mark III digital camera, video recording frame rate were set as 25 fps and 60 fps respectively.

Videos of flying male *Luciola* nr. *nicolleiri* displaying light signals were taken by a Sony Alpha 7S digital camera, video recording frame rate were set as 25 fps, 50fps and 100 fps respectively.

All the videos are imported into TiLIA - A software package for image analysis of firefly flash patterns. It is a time-lapse image analysis (TiLIA), a free open-source software package for signal and flight pattern analyses of fireflies that uses video-recorded image data. TiLIA enables flight path tracing of individual fireflies and provides frame-by-frame coordinates and light intensity data (Konno et al., 2016). Version WIN 10 (64bit) was used.

Data was exported as CSV format, the CSV files contains the relative intensity of the light spot (as photons per pixel) for every image frames, in time sequence. For a video captured at 100fps, there are 100 image frames in one second, representing the time sequence of 10 ms, 20 ms, 30 ms, … 990ms and 1000ms. For a video captured at 25fps, there will be 40 image frames in one second, representing the time sequence of 25ms, 50ms, 75ms, … 975ms and 1000ms. Line graph of

each video clip is made from the CSV files by Microsoft Excel, showing the relative light spot intensity against time in milliseconds.

Long exposure photos were also taken for flying male of all the three species. Long exposure photos were all taken by a Canon EOS 5D Mark III digital camera fixed on a tripod. It could be taken by one shot, exposure time ranging from 5s to 30s; or overlaying multiple images taken within a time period at the same place, using Adobe Photoshop 5.1 CS. For example, overlapping 50 images, exposure time of each is 10s, total exposure time would be 500s, containing more flashes in the combined image, showing more variation of the flash pattern. 500s exposure time in one take would result in an image with the background too bright to see any light spots emitted by the fireflies.

RESULTS

Flash signal of *Pteroptyx maipo* flying male

Long exposure photo (Fig. 1) shows that the signal consists of interval flashes, each flash is composed of 7-16 closely connected pulses.

Line graph exported from 100fps video (Fig. 2) shows that the signal consists of interval flashes, each flash is composed of 16 closely connected pulses. Flash duration range from about 500ms to 600ms; inter-flash duration is 2000ms. Pulse duration ranges from 31ms-38ms.

Line graph exported from 50fps video (Fig. 3) shows that the signal consists of interval flashes, each flash is composed of 7-15 closely connected small pulses. Flash duration range from about 480ms – 520ms; inter-flash duration is 2600ms. Pulse duration is about 35ms.

Line graph exported from 25fps video (Fig. 4) shows that the signal consists of interval flashes. Flash duration range from about 600ms – 700ms; inter-flash duration is 2500ms.

Flash signal of *Curtos fulvocapitalis* flying male

Long exposure photo (Fig. 5) shows that the signal consists of interval flashes, each flash is composed of 2 separated pulses.

Line graph exported from 60fps video (Fig. 6) shows that the signal consists of interval flashes, each flash is composed of 2 independent pulses. Flash duration is 190ms; inter-flash duration ranges from 2000ms to 2500ms. Pulse duration is 70ms; inter-pulse duration is 50ms.

Figure 1. Long exposure photo of *Pteroptyx maipo* flying males displaying light. Photo by author.

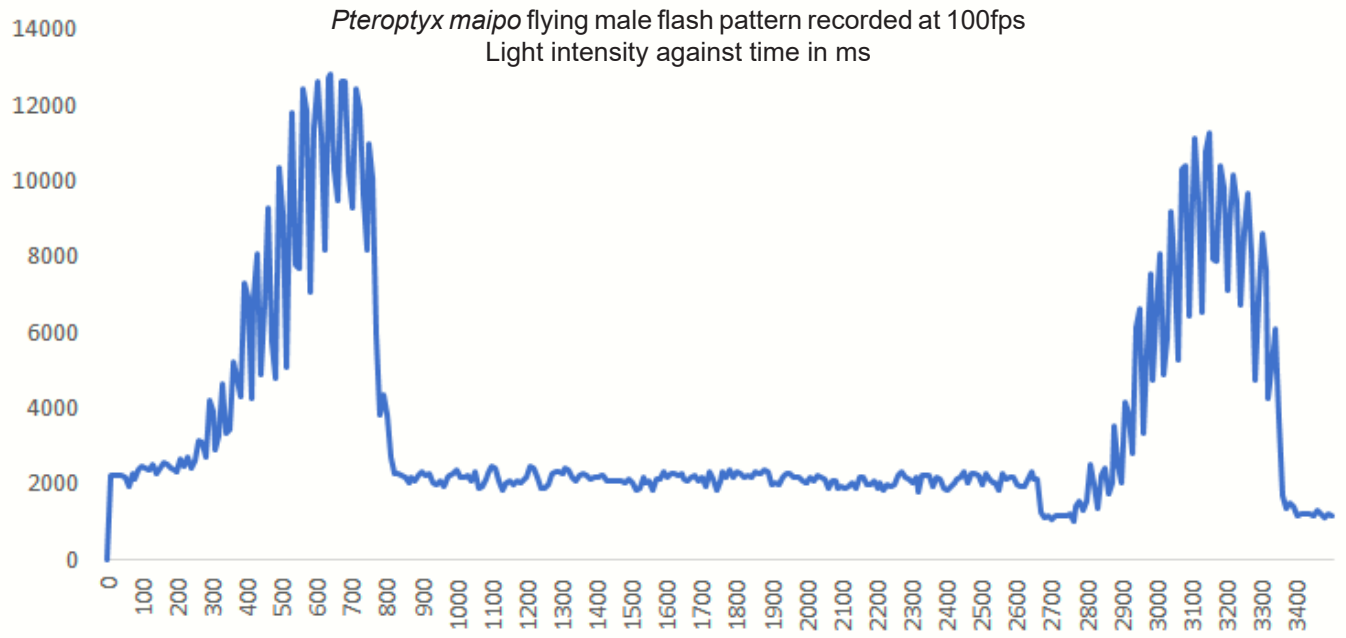

Figure 2. *Pteroptyx maipo* flying male flash pattern recorded at 100fps.

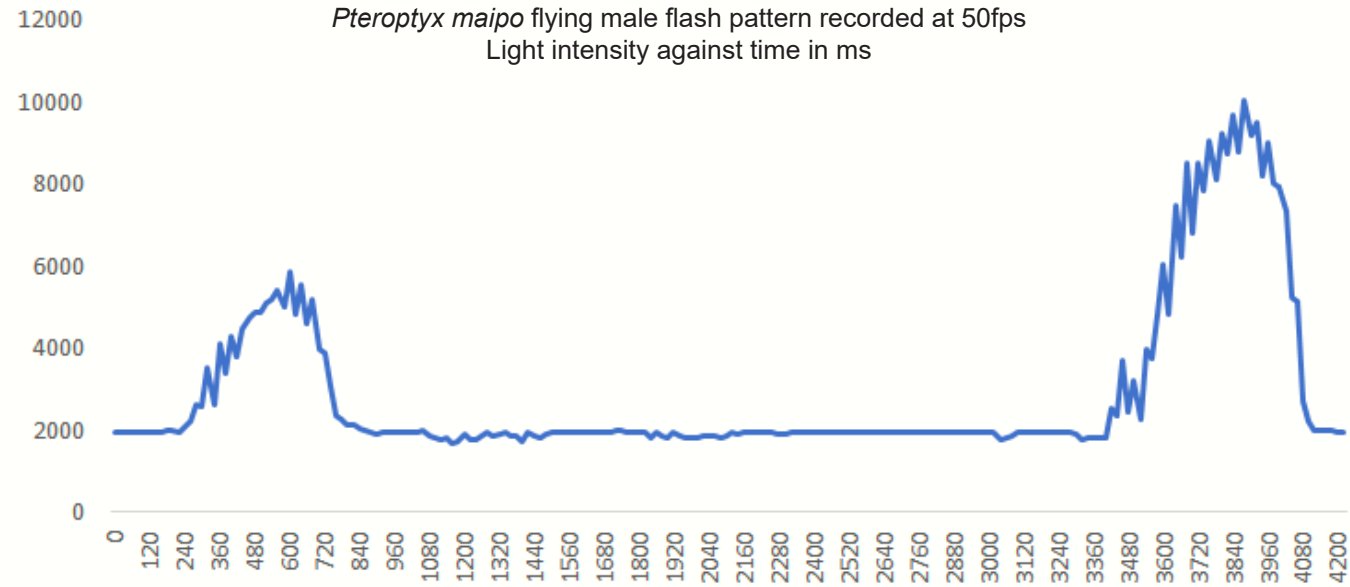

Figure 3. *Pteroptyx maipo* flying male flash pattern recorded at 50fps.

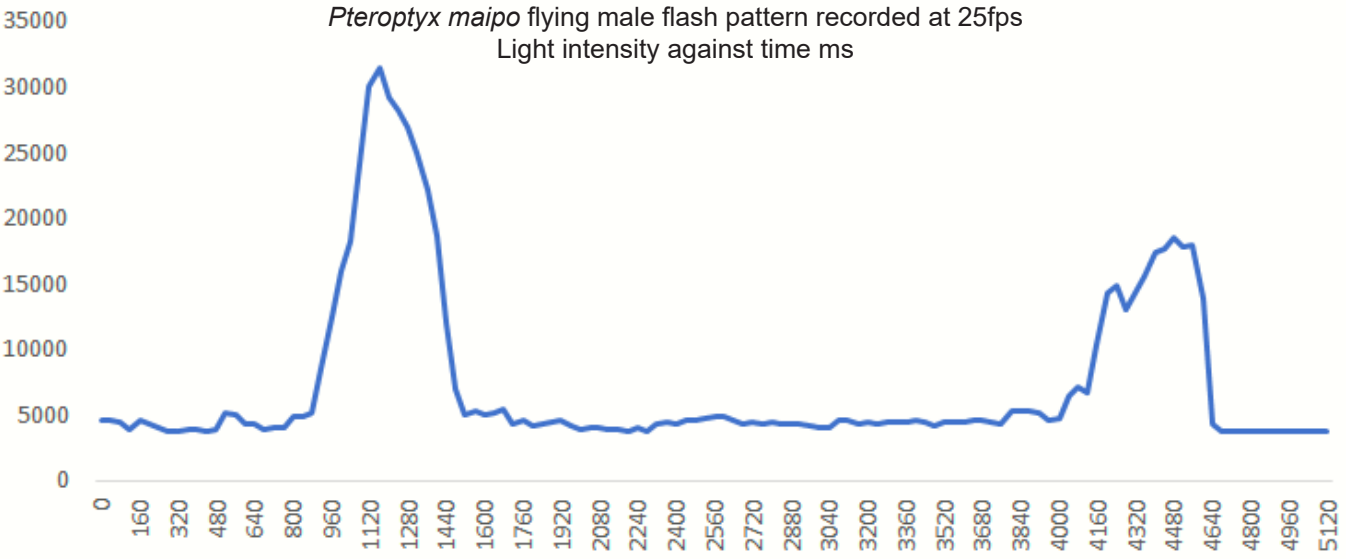

Figure 4. *Pteroptyx maipo* flying male flash pattern recorded at 25fps.

Line graph exported from 25fps video (Fig. 7) shows that the signal consists of interval flashes, each flash is composed of 2 closely connected pulses. Flash duration range from about 240ms – 280ms; inter-flash duration ranges from 1600ms to 2000ms. Pulse duration is 120ms – 140ms.

Flash signals of *Luciola* nr. *nicolleiri* flying male

Long exposure photo (Fig. 8) shows that the signal consists of interval flashes, flashes are composed of 2 closely connected pulses, the earlier pulse is much weaker than the latter.

Line graph exported from 100fps video (Fig. 9) shows that the signal consists of interval flashes, each flash is composed of 2 closely connected pulses, the earlier pulse is much weaker than the latter. Flash duration ranges from 220ms to 240ms; inter-flash duration ranges from 370ms to 390ms. Duration of the earlier, weaker pulse ranges from 50ms to 70ms; duration of the latter, stronger pulse ranges from 150ms to 160ms.

Line graph exported from 50fps video (Fig. 10) shows that the signal consists of interval flashes. Flash duration is about 160ms; inter-flash duration ranges from 380ms to 420ms.

Line graph exported from 25fps video (Fig. 11) shows that the signal consists of interval flashes. Flash duration ranges from about 320-360ms; inter-flash duration ranges from 200ms to 400ms.

DISCUSSION

For *Pteroptyx maipo*, all the pulses of each flash shown on the long exposure photo and the flash pattern graph recorded at 100fps are not shown on the graph recorded at 25fps. Some of the pulses are not shown on the graph recorded at 50fps. Using 25fps or 50fps is not able to able to give a true representation of *Pteroptyx maipo* flying male flash pattern.

For *Curtos fulvocapitalis*, the two pulses, although close to each other, are separate. This is clearly shown on the long exposure photo and the graph recorded at 60fps. The two pulses on the flash pattern graph recorded at 25fps appear are connected. Using 25fps is not able to accurately recorded flash pattern of *Curtos fulvocapitalis* flying males.

For *Luciola* nr. *nicolleiri*, a weaker pulse appears before the stronger pulse of every flashes, this is only shown on the long exposure photo and the graph recorded at 100fps. Not represented in the graph recorded at 50fps and that recorded at 25fps. Using 25fps or 50fps is not

Figure 5. Long exposure photo of *Curtos fulvocapitalis* flying males displaying light. Photo by author.

able to give a true representation of *Luciola* nr. *nicolleiri* flying male flash patterns.

Flash pattern graph recorded at 25fps also show a longer flash duration for *Curtos fulvocapitalis* and *Luciola* nr. *nicolleiri* compared with that recorded at 100fps.

Slower frame rate means longer exposure time for a single frame/image. For 25fps, the exposure time of every frame is at most 40ms (see remark). When an instant change of light intensity happens at any moment within this frame, the ambiguity period is 40ms (see Fig. 12). Amplitude of any instant variation will be more "diluted" within a longer exposure time because the image of one frame only shows the cumulative result but not any variation within the exposure time. Faster frame rate results in shorter ambiguity period and less dilution of instant variations, and therefore more accurate results.

For recording firefly flash, narrower shutter angle lower the "dilution" effect, but has no influence on duration of ambiguity, very likely, cannot improve the inaccuracy of recording firefly flash pattern by lower frame rate videography. Narrower shutter angle means shorter exposure time for each image and the firefly flashes on the image will be darker.

Although faster frame rates give more accurate results. There are a number of limitations and considerations:

1. Only some high grade digital video cameras in the market provide 100fps settings;

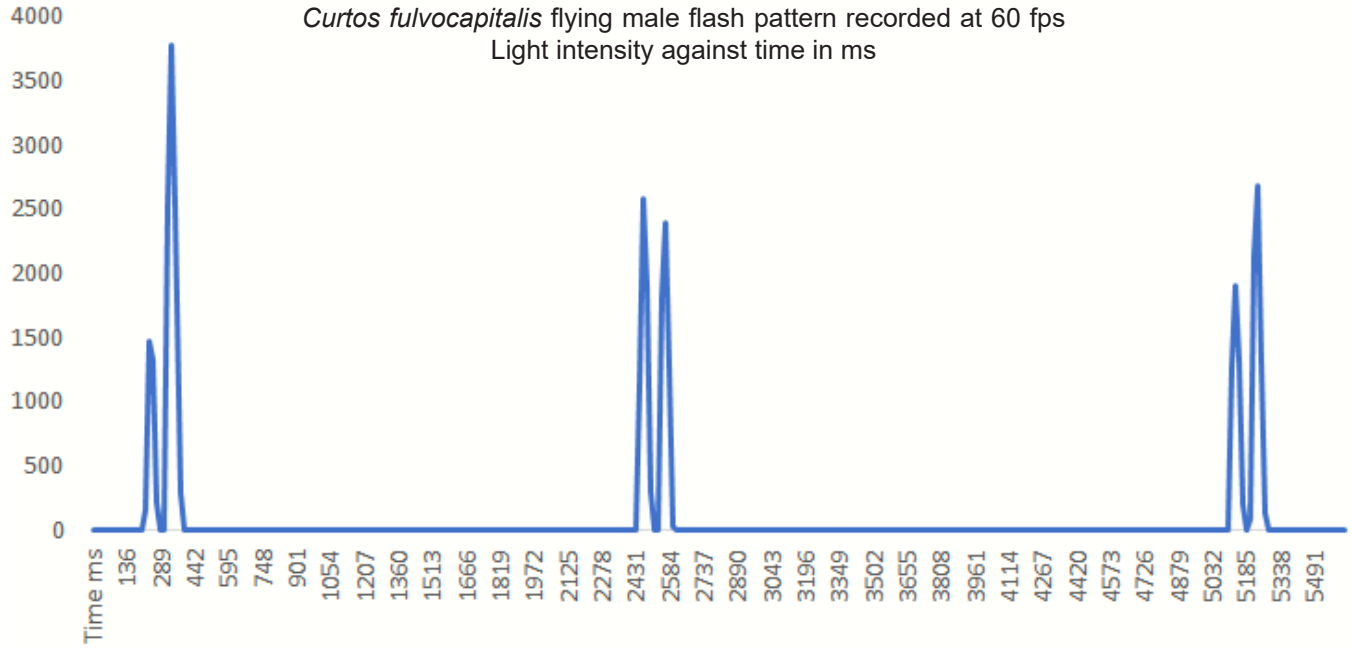

Figure 6. *Curtos fulvocapitalis* flying male flash pattern recorded at 60fps.

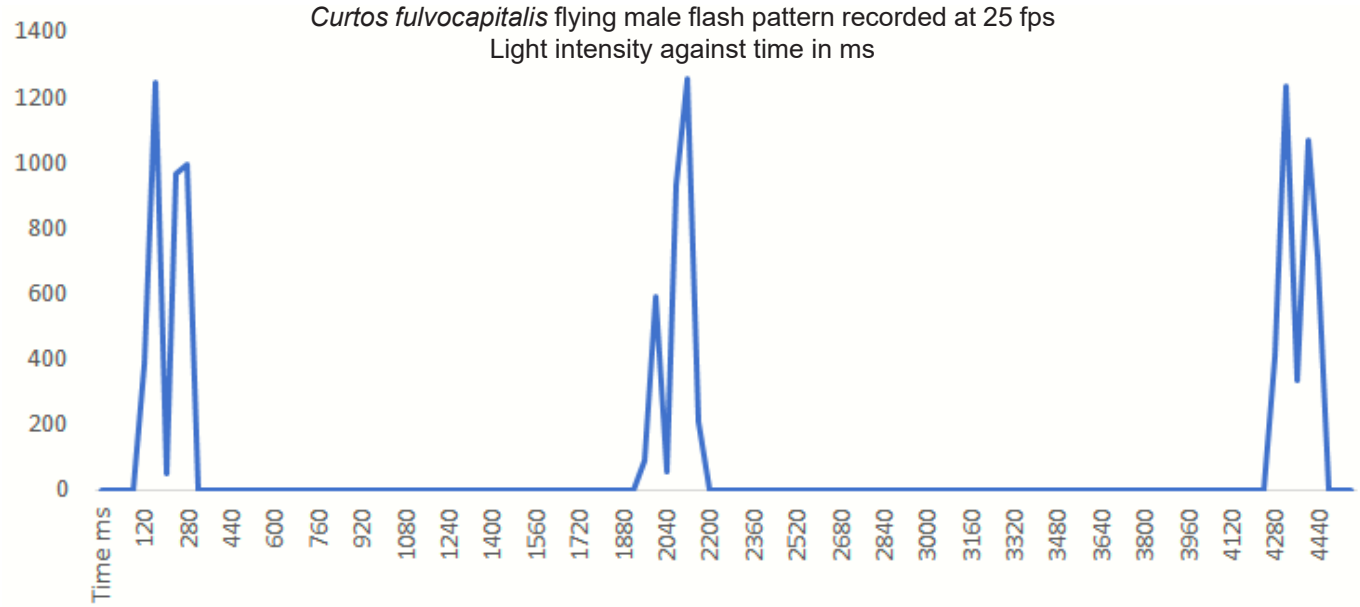

Figure 7. *Curtos fulvocapitalis* flying male flash pattern recorded at 25fps.

2. Higher frame rate often result in lower resolution of the video, for example, lower from 1920 x 1080 pixels to 1280 x 720 pixels, lower resolution also affect accuracy of the flash pattern analysis by the software;

3. Higher frame rate means shorter exposure time for each frame/image, the firefly flashes on the image will be darker. This need to be corrected by increasing the lens aperture, or increasing the sensor sensitivity (ISO value). The former would reduce depth of view, firefly flashes on the images would become more blurry; the latter would increase noise level of the images which could also influences accuracy of the flash pattern analysis by the software.

CONCLUSION

Using 25fps to record firefly flash pattern may produce false results. Using 50fps to record firefly flash pattern may produce inaccurate results. Flash pattern of majority of the Luciolinae firefly species have not been recorded and reported yet. To ensure validity, using video recording at 100fps or higher is highly recommended.

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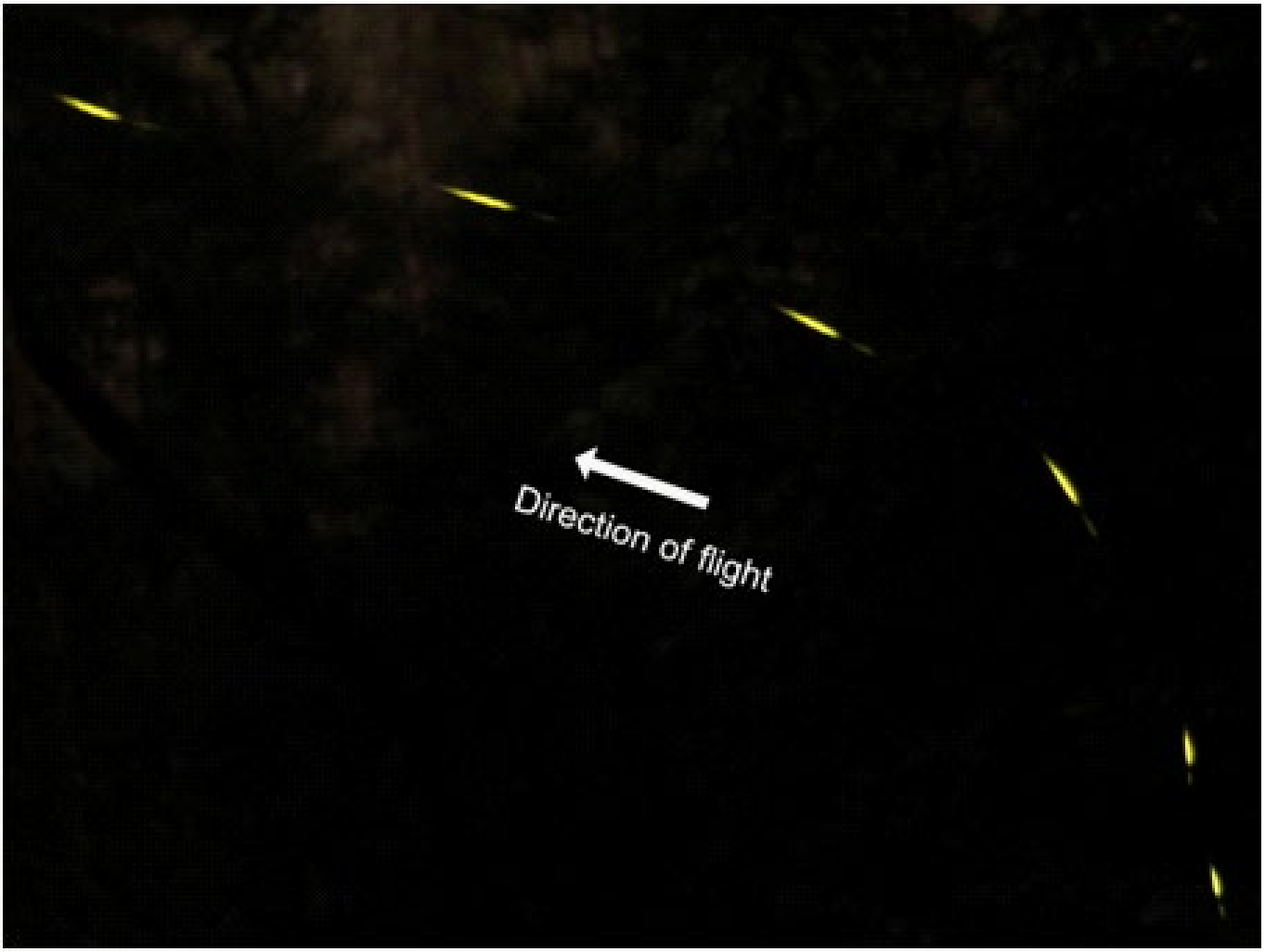

Figure 8. Long exposure photo of a *Luciola* nr *nicolleiri* flying male displaying light. Photo by author.

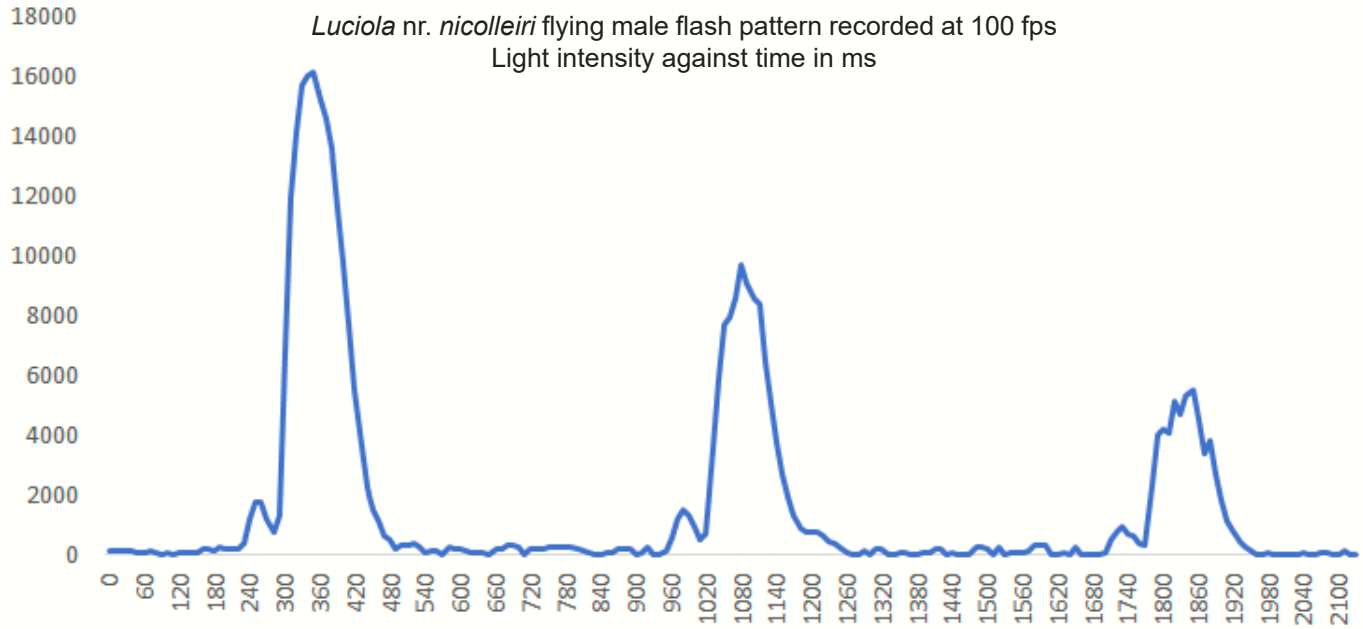

Figure 9. *Luciola* nr. *nicolleiri* flying male flash pattern recorded at 100fps.

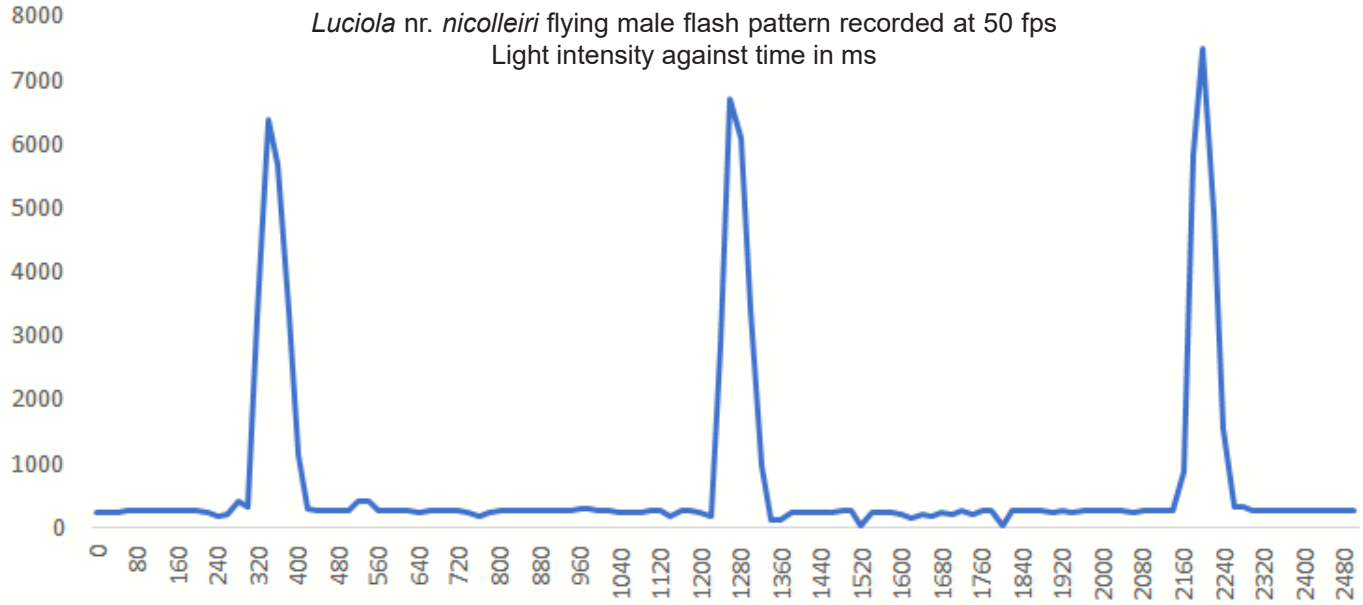

Figure 10. *Luciola* nr. *nicolleiri* flying male flash pattern recorded at 50fps.

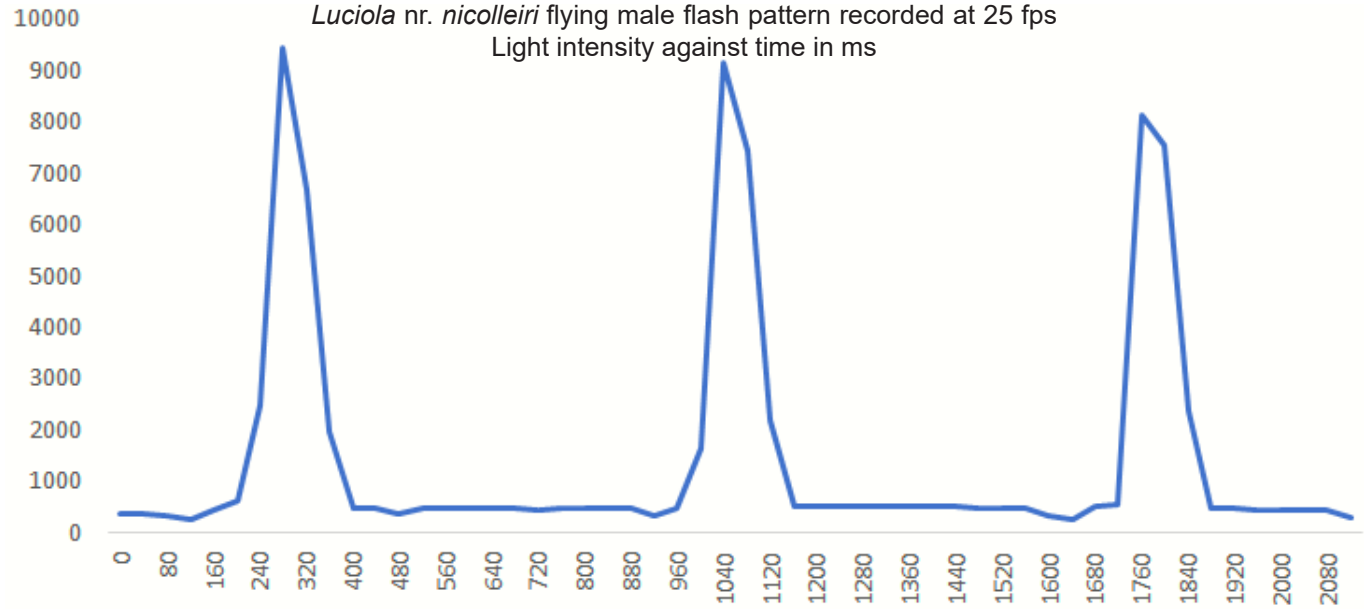

Figure 11. *Luciola* nr. *nicolleiri* flying male flash pattern recorded at 25fps.

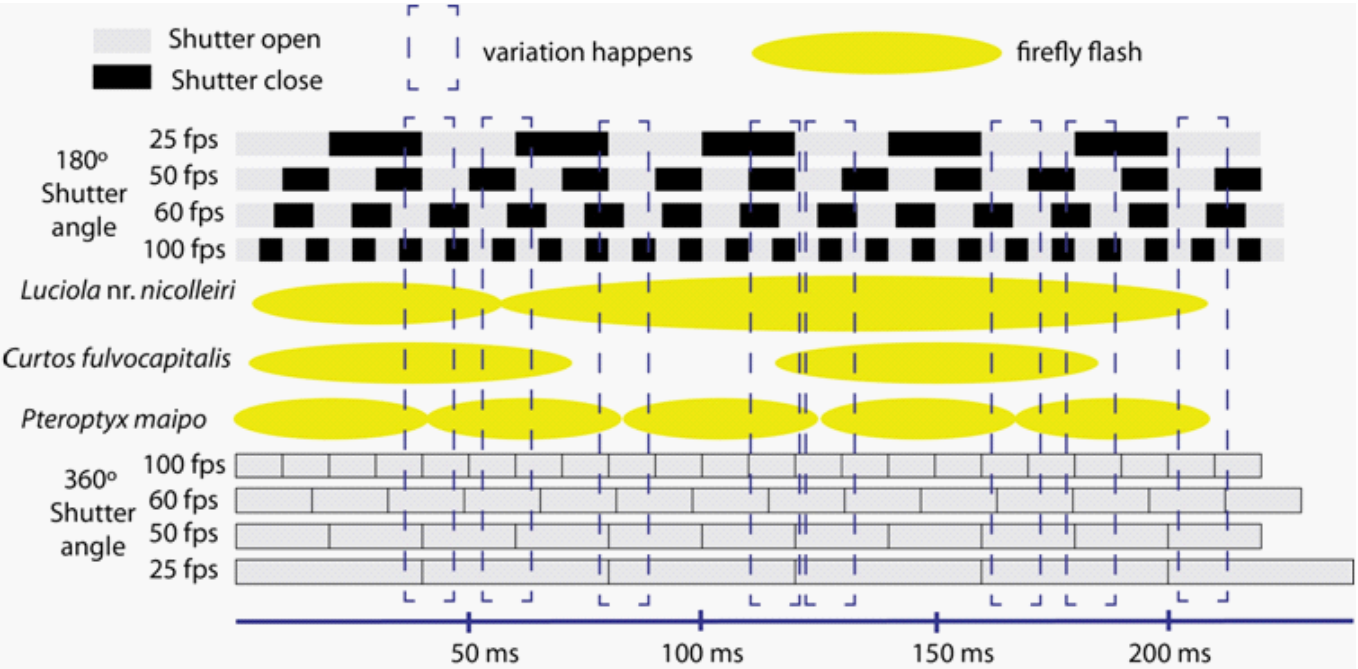

Figure 12. Different frame rates and shutter angles for recording flash pattern of three Luciolinae fireflies. [Remark: Shutter angle is regarded as amount of time when the shutter of the video camera is open in each frame. For example at 25fps, duration of each frame is 40ms, shutter could be kept open for 40ms (shutter angle 360o) or shorter. If the shutter is open for 20ms, the other 20ms the shutter is closed. Shutter angle is 180o for this situation. If the shutter is open for 5ms, shutter angle is 45o. Narrower shutter angle results in less “blurry” videos for fast moving objects. Shutter angles may or may not be adjustable, depends on different video recorders]

