

Depletion of Firefly Species in Delaware: a Comparative Study

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Abstract: *In Delaware, it is projected that the sea level will rise between 0.5 and 1.5 meters by the year 2100, thereby significantly altering wetland ecosystems and modifying the distribution patterns of species dependent on wetlands. This predicament presents a challenge for the enigmatic lantern firefly species, which is endemic to Delaware and belongs to the Photuris genus. The lantern firefly relies on floodplains situated at an elevation of less than 1 meter above sea level. Conversely, there is minimal research on the Say's Firefly (Pyrrhopyga angulata), another firefly that is also found in Delaware, and hence, it remains unclear what is causing its decline. Why focus on fireflies? Fireflies, like many other forms of wildlife, are subject to the pervasive influence of human activities across all levels. Fireflies are impacted by habitat fragmentation, increasing deforestation and urbanization, rising sea levels, and light pollution. If humans fail to pay attention, the act of chasing fireflies on a warm summer night may become a memory. Notably, reports indicate that the ongoing sixth mass extinction, unlike previous extinctions driven by natural phenomena, is primarily propelled by human activity. The research aims to identify the areas inhabited by both firefly species, using a methodology of comparative analysis of their respective distribution map. This will be done through statistical analysis on two open source datasets, one for each type whereby we will be using the dataset with more information to derive inferences on the less researched one. Fireflies play a crucial role in maintaining food web stability as both predators and prey. With their substantial diets and preference for snails and slugs, they contribute to agricultural environments. Moreover, the bioluminescent glow emitted by fireflies serves as a dietary component for numerous animal species. Therefore, it is imperative to analyze the factors contributing to the decline of fireflies in order to potentially reduce the effects of unknown climatic factors and consequences.*

Keywords: Say's Firefly, Mysterious Lantern Firefly, Conservation, Extinction, Climate Change

1. Introduction

In Delaware, *Photuris Mysticalampas* and *Pyrrhopyga angulata*, two firefly species, face population decline. *Photuris Mysticalampas* is threatened by rising sea levels, while *Pyrrhopyga angulata*'s decline lacks a clear cause. [1]

Fireflies play a crucial role in maintaining food web stability as both predators and prey. With their substantial diets and preference for snails and slugs, they contribute to agricultural environments. Moreover, the bioluminescent glow emitted by fireflies serves as a dietary component for numerous animal species. [2] But fireflies, like many other forms of wildlife, are subject to the pervasive influence of human activities. They are impacted by habitat fragmentation, increasing deforestation and urbanization, light pollution and rising sea levels [3]. All of these, in fact, are being caused by human - led actions which are leading to global warming and hence depleting the population of precious species. Studies show how the loss of an organism can disrupt the environment which could lead to the potential destruction of our planet. This is in great alignment with the Sixth Mass Extinction, which is primarily propelled by human activity. [4]

Data from multiple sources talk about the depletion of the fireflies belonging to the *Photuris* Genus or/and the lack of data on Say's Firefly. For example: A study by Lewis et al claims that a species of the *Photuris* Genus found in Delaware (*Photuris Bethianensis*) is threatened by sea level. [5] Another study by Lewis analyzes the IUCN's Red List against certain quantitative thresholds and highlights how *Photuris Mysticalampas* is being endangered due to sea level

rise. Lewis's study doesn't have much information on Say's Firefly [6].

Even though the aforementioned lack of data on a particular firefly species might seem insignificant, the uncertainty in its cause of decline is attributed to the fact that there is minimal data on the Say's Firefly.

In fact, the problem of lack of data is discussed by many scientists. For example: Montgomery's study focuses more on research recommendations as a lot is left to be searched on insect declines in general. He furthermore mentions how it is imperative to fill data gaps so that the problem of lack of data can be prevented and more credible results can be obtained [7]. The discussion on the paucity of data is also done by Goulson. He posits that even with the available evidence, there have been large declines in insect populations due to the lack of fundamental data [8]. Reed's study tries to refute the statement "risk factors and threats are the same" and claims that this confusion arises due to a lack of foundational data [9].

To prevent declines in insect populations due to the paucity of baseline data, a study discusses eight empirical articles and persuades people towards the adoption of pro - environmental behaviors. Didham is positive about the insect conservation scenario and feels that growing technology will accelerate the development process and provide greater insight into how environmental conditions and anthropogenic drivers will impact insect species, leading to more authentic results for the firefly species. [10]

Nevertheless, this research aims to identify the common areas inhabited by both firefly species, using a methodology

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of comparative analysis of their respective distribution map and various factors associated with it. This will be done through a qualitative analysis of existing findings in the literature to derive inferences from the less researched ones.

2. Methods

The respective distribution maps of their species were analyzed and Delaware was chosen as the place of focus. This was because *Photuris Mysticalampas* is primarily found in Delaware and the *Pyractomena Angulata* was declining in the mid - Atlantic region which encompassed Delaware among others. *Pyractomena Angulata* was not declining in

any other places across its range apart from the mid - Atlantic region.

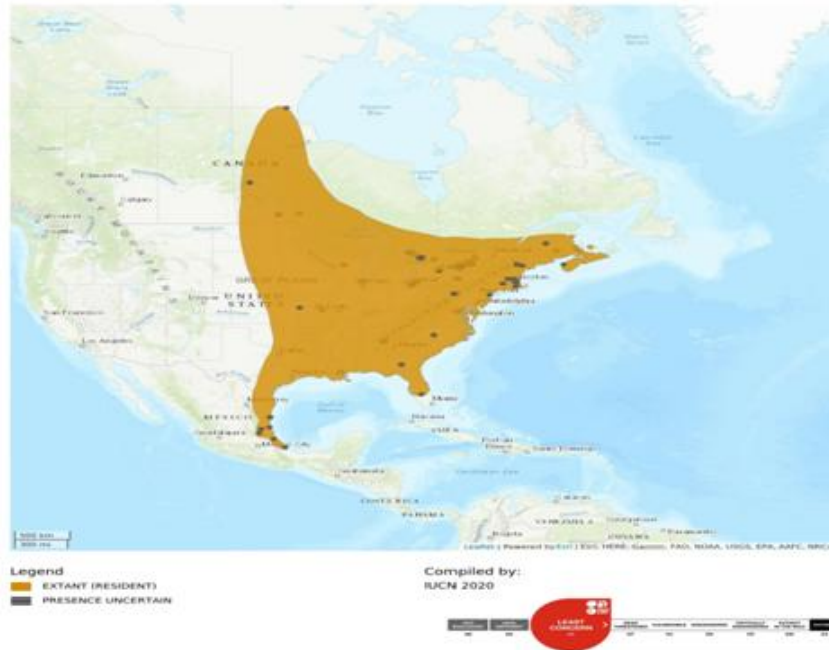
Photuris Mysticalampas and *Pyractomena Angulata* were then assessed on a variety of variables like classification, conservation status, threats and population trends, and factors associated with ecology and life history. These variables or categories were chosen after gathering data from multiple sources and finding potential points of comparison for these two fireflies.

Respective distribution maps of both the species

Distribution Map of *Pyractomena Angulata* [1]

<https://www.iucnredlist.org/species/164044783/1667713>

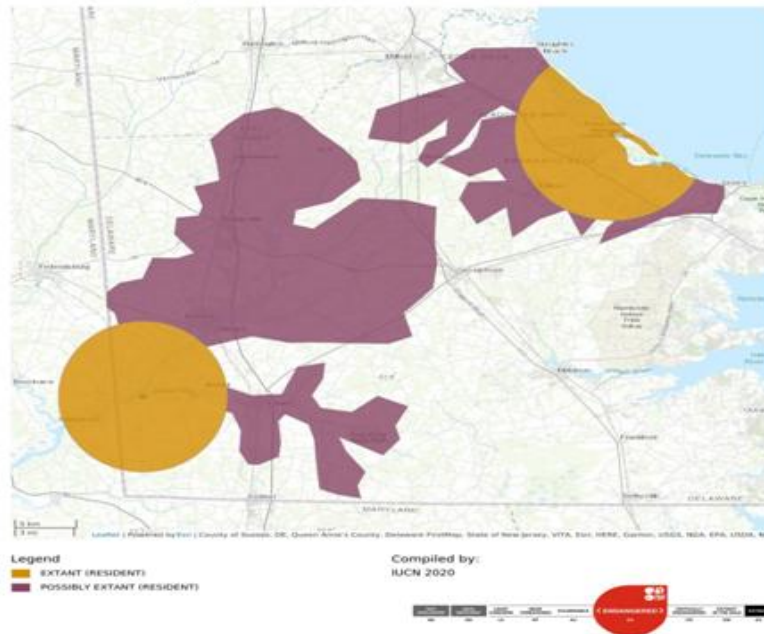
Distribution Map



Distribution Map of *Photuris Mysticalampas* [1]

<https://www.iucnredlist.org/species/164045835/166771508>

Distribution Map



1) Classification

Before delving into the nuances of a comparative study, it is imperative to understand the basic biological taxonomy of the intended research species. Classification helps to know

the origin and evolution of species. It helps to determine the exact position of the organism in the classification and develop phylogenetic relations between different groups of organisms.

Species	Kingdom	Phylum	Class	Order	Family	System
Photuris Mysticalampas (Mysterious Lantern Firefly)	Animalia	Arthropoda	Insecta	Coleoptera	Lampyridae	Terrestrial (forested peatland floodplains)
Pyractomena Angulata (Say's Firefly)	Animalia	Arthropoda	Insecta	Coleoptera	Lampyridae	Terrestrial (both moist and dry forests)

2) Other factors

The fireflies were then compared over the global status, last review date (this was put to see if these species were really getting ignored), methods used (to understand the authenticity and accuracy of the methods), the US Endangered Species Act (whether they had been listed under the act), the EOO among others.

presumed extinct and possibly extinct respectively. This system also entails categories like DD (Data Deficient), NE (Not Evaluated), and CD (Conservation Dependent).

As far as the global status is concerned, the Provincial and Global Ranking Systems rank the global status of species from G1 to G5 (G1=imperiled, G5=secure). Apart from these 5 rankings, two additional rankings GH and GX mean

Extent of Occurrence (EOO), as the name suggests, refers to the area contained within the shortest continuous imaginary boundary which can be known to draw to encompass all the known, inferred, or projected sites of present occurrence of a species. The estimated number of element occurrences refers to the number of the particular species within the EOO (Extent of Occurrence).

Species	Global Status	Last Reviewed	Method Used	US Endangered Species Act	EOO	Estimated Number of Element Occurrences
Photuris Mysticalampas (Mysterious Lantern Firefly)	G1	12.23.2021	Calculator	Not Listed	1050 KM ²	1 - 5
Pyractomena Angulata (Say's Firefly)	G5	1.2.2022	Calculator	Not Listed	8 Million KM ²	81 - 300

3) Population trends and other factors

Consequently, the population trends, the conservation status, and the susceptibility to environmental factors were assessed.

Species	Population Trend	Conservation Status	Fragility
Photuris Mysticalampas (Mysterious Lantern Firefly)	Declining	Critically Imperiled	Moderately Vulnerable
Pyractomena Angulata (Say's Firefly)	Declining	Least Concern	Moderately vulnerable

4) Ecology and history

To include every possible distinction factor, these fireflies were assessed on ecology and life history which were divided into 2 subcategories: 1) habitats, and 2) phenology.

supporting a variety of firefly species. Lacustrine habitats are known as still water ecosystems while Riverine habitats are known as flowing water ecosystems.

Habitats included Estuarine, Lacustrine, and terrestrial habitats. Estuarine habitat is the one where fresh water from rivers and streams mixes with the salty ocean water hence

Phenology, a branch of science dealing with relations between climate and periodic biological phenomena (such as bird migration or plant flowering), was also included to discuss flying trends and food habits.

a) Habitats

Species	Habitat Type	Estuarine Habitats	Lacustrine Habitats	Riverine Habitats	Terrestrial Habitat
Photuris Mysticalampas (Mysterious Lantern Firefly)	Freshwater	Forested Wetland	Bog/Fen	Peatland Floodplains	Not mentioned
Pyractomena Angulata (Say's Firefly)	Terrestrial	Herbaceous Wetland	Bog/Fen	Medium river, creek, big river	Woodland, chaparral

b) Phenology

Species	Flying Pattern	Food Habits
Photuris Mysticalampas (Mysterious Lantern Firefly)	Flies from mid - June to Late July	Invertivore
Pyractomena Angulata (Say's Firefly)	Not mentioned	Predacious

NatureServe. "Pyractomena Angulata. " NatureServe Explorer: An Online Encyclopedia of Life https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.747835/Pyractomena_angulata.

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NatureServe. "Photuris Mysticalampas." NatureServe Explorer: An Online Encyclopedia of Life https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.902376/Photuris_mysticalampas.

3. Results

Some inferences can be drawn from this comparative analysis between *Pyractomena Angulata* and *Photuris Mysticalampas*.

It is evident that the conservation status of the Say's Firefly (*Pyractomena Angulata*) is the least concern but it's mentioned that its population trend is decreasing. The population trend for the Mysterious Lantern Firefly is declining and its conservation status is endangered.

When further assessed, it was found that the global status of *Photuris Mysticalampas* was G1 (impered) and that of *Pyractomena Angulata* was G5 (secure).

The EOO (Extent of Occurrence) was 1050 km² and 8 million km² for *Photuris Mysticalampas* and *Pyractomena Angulata* respectively. The estimated number of element occurrences refers to the number of the particular species within the EOO (Extent of Occurrence). This occurrence of the species was 1 - 5 (approximately) for *Photuris Mysticalampas* and 81 - 300 for *Pyractomena Angulata*.

Both of the species were moderately vulnerable to environmental stresses and external factors.

Furthermore, while the Mysterious Lantern firefly was a specialist species, the Say's firefly was a generalist species. A generalist can thrive in a wide variety of environmental conditions and can make use of a variety of different resources. On the other hand, a specialist species can thrive only in a narrow range of environmental conditions and has a limited diet.

The habitats the fireflies occupy also play a quintessential role in determining the amount to which they are affected by certain factors/threats. *Photuris Mysticalampas* occupied the freshwater - like habitat while *Pyractomena Angulata* generally occupied the terrestrial habitats. Estuarine habitats occupied by the *Photuris Mysticalampas* were the forested wetlands and for the Say's Firefly, they were the herbaceous wetlands. Riverine habitats occupied by the *Photuris Mysticalampas* were the peatland floodplains and for the Say's Firefly, they were the medium, big rivers. Furthermore, Lacustrine habitats were bog/fen for both the studied species. The terrestrial habitat wasn't mentioned for the lantern firefly but was specified as woodland, chaparral for the Say's firefly.

Based on their food habits, the lantern firefly was found to be invertivore (feeding on invertebrates) while Say's Firefly was found to be predacious (feeding on very small dead microorganisms).

Although these results are exciting and provide a lot of scope, certain discussions need to be done to address specific points of concern and confusion.

4. Discussion

The minimal data on *Pyractomena Angulata* (Say's Firefly) can be attributed to the fact that the present population is spread out, owing to its vast EOO. Even though all the evidence for *Pyractomena Angulata* - its number of element occurrences, its EOO, its generalist nature - might hint to the fact that the conservation status of it as being "least concern" is justified, its continuous decline (especially in the mid Atlantic Region) hints to the fact that there are some unknown factors at play which are causing its decline.

Say's Firefly is a generalist meaning that it should be tolerant of different environmental conditions which could protect it from depletion but its population trend is mentioned as decreasing and conservation status as least concern.

The problem between population trend and conservation status can be attributed to the fact that though the population of the Say's firefly is indeed in decline, the conservation status is stated as the least concern because the population hasn't reached a threshold level to be put into the high concern category.

The last date they were reviewed strengthened the findings: *Pyractomena Angulata*'s last review date was 1.2.2022 indicating that, fortunately, the population had not reached the threshold value as of 1.2.2022. Such reviews are conducted rarely because of the assumption that the species is "Least Concern". Therefore, no data from then has been released with updates on the population trend and the conservation status of the *Pyractomena Angulata*.

Since no updates on the population of *Pyractomena Angulata* have been released since its last review date, its population must likely have crossed the threshold level at least in areas of the Mid - Atlantic (including Delaware) where there were previously huge declines [11]. It is also the region of the Mysterious Lantern Firefly which is depleted due to the rise in sea levels. Therefore, inferences can be derived from the more documented one to account for the less documented one.

It can be concluded that the depletion of *Pyractomena Angulata* in the mid - Atlantic region might also be occurring due to the rise in sea levels. This might be possible due to 1) *Photuris Mysticalampas*'s association with tidal freshwater floodplains that occur less than 1 m above sea level. The rise and associated storm surges would completely inundate most of the habitats that *Photuris Mysticalampas* currently utilizes [13]. This could also potentially lead to the depletion of *Pyractomena Angulata* which also occupies similar habitats.

Another reason for the depletion of *Pyractomena Angulata* can be light pollution. This can be seen in the case of another firefly of its genus: *Pyractomena Borealis*. It was affected by light pollution and invasive species while still

having an EOO of 9 million km² (an EOO very similar to that of *Pyrrhopygia Angulata*). [14]

Apart from taking immediate measures to save *Photuris Mysticalampas* (currently classified as “endangered”), the reviews of *Pyrrhopygia Angulata* should be given more importance as its conservation status is stated as “Least Concern” and it’s in decline. It wouldn’t be long to put the species into the high concern category.

5. Conclusion

The study’s findings underscore the urgency of reevaluating the conservation status of *Pyrrhopygia Angulata* currently classified as “Least Concern”. The study aims to test these next steps by developing mechanisms for regularly monitoring the firefly population (especially *Pyrrhopygia Angulata*) to check if they are still below the threshold level. Investing more in the research of fireflies so that they are regularly researched and observed how the population trend is changing over the years. Protecting and restoring firefly habitats to ensure they have adequate spaces for breeding and foraging, and implementing strategies to reduce light pollution to aid their reproduction.

6. Limitations

The results are very exciting and provide a lot of potential in the field of fireflies but there are certainly some limitations to the study which need to be considered.

The biggest problem is expected to be the lack of data on the fireflies or the incredibility of data. Fireflies are enigmatic creatures so having access to them is not always possible. Additionally, with the paucity of data, it might not be known when exactly the population of *Pyrrhopygia Angulata* would cross the threshold level. Therefore, it is imperative to regularly monitor their populations, especially in the mid - Atlantic region where they are facing huge declines. The lack of statistical analysis means that it might be difficult to draw credible conclusions as to how the firefly population has changed over the years. It might be possible that the number of element occurrences within the EOO might be inaccurate due to the lack of data.

The ecological conditions and habitat of firefly populations can vary greatly. Research conducted at one location may not apply to other regions or ecosystems, thus limiting the generalizability of the findings. Mistakes or inaccuracies in data collection methods could lead to bias in the results. The two firefly species may have very different life histories or ecological niches. These differences could impact their susceptibility to depletion factors, and failure to account for these depletion factors might lead to misleading conclusions. Finally, correlation does not always imply causation, unaccounted variables could influence the observed patterns.

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