Final Project

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December 5, 2021

1 Introduction

Shortly after moving into our newly purchased house, we discovered an infestation of brown recluse spiders. While researching how to manage the spider infestation, I discovered a research by M. A. Navarro-Silva, et al. (2010) in the Journal of Economic Entomology. He studied the effects of different pyrethroid insecticides on the brown recluse spider species, *Loxosceles intermedia*, by conducting controlled laboratory experiments on the mortality rates of four different chemical compounds at several concentrations each. He concluded microencapsulated lambda-cyhalothrin (MELC) was most effective at killing the spiders. This project paper seeks to apply bayesian techniques to the mortality data published by Navarro-Silva in order to determine the median lethality concentration (LC_{50}) levels for the brown recluse spider.

2 Research Overview

Navarro-Silva selected four insecticides commonly used to treat spider infestations. The susecptibility of *L. intermedia* to each chemical was evaluated by collecting live samples of the spiders and exposing them to various concentrations of the insecticides in controlled petri dishes. The mortality of each spider was evaluated at different time intervals up to 24 hours. Figure 1 is a copy of the morality rates published in Navarro-Silva's paper for *L. intermedia* spiders exposed to microencapsulated lambda-cyhalothrin at varying concentrations.

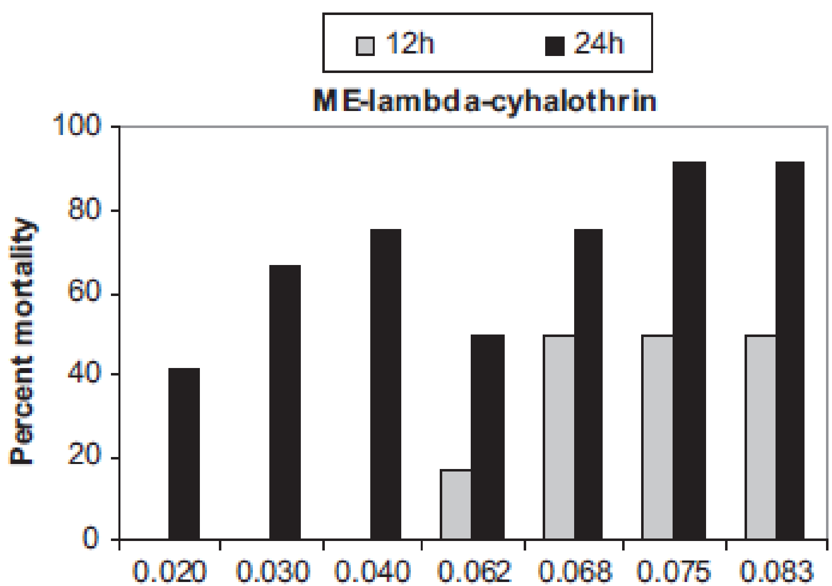

Figure 1: Mortality rates of spiders exposed to microencapsulated lambda-cyhalothrin (source: M. A. Navarro-Silva, et al. (2010))

The median lethal concentration level for MELC was calculated using classical probit analysis and found to be $LC_{50} = 0.023$ mg/kg.

3 Methodology

This project uses bayesian logit, probit, and log-log models to estimate the LC_{50} for the different insecticides given the mortality rates published by Navarro-Silva. The logit model uses logistic sigmoid function and takes the form

$$log(\frac{p}{1-p}) = \beta_0 + \beta_1 x_1$$

where p is the probability of survival and x is the insecticide concentration. The probit model is similar to the logit model, but uses the normal sigmoid function instead of the logistic function.

The log-log model takes the form

$$log(p) = \beta_0 + \beta_1 log(x_1)$$

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To determine the LC_{50} level, I added an extra data point with a morality rate of 50% and an unknown concentration. WinBUGS was used to estimate the concentration that would deliver the median lethal concentration to achieve a mortality rate of 50%. The unknown concentration was initialized using a uniform distribution between 0 and 1.

4 Results

Table 1 summarizes the median lethal concentrations as calculated using the logit, probit, and log-log models.

Method	LC_{50}	95% Credible Set
Navarro-Silva (probit)	0.023	
Bayes logit model	0.021	(0.00309, 0.03869)
Bayes probit model	0.021	(0.00314, 0.03908)
Bayes log-log model	0.059	(0.00436, 0.74670)

Table 1: Median lethal concentration of MELC

Navarro-Silva, et al, reported a $LC_{50} = 0.023$ mg/kg with a range of $(0.006347-0.033684)$ mg/kg). Their paper did not specify the confidence level of the reported range. However, the bayes logit and probit models from this project had very similar results with idential estimations of $LC_{50} = 0.021$ mg/kg and 95% credible sets of $(0.00309, 0.03869)$ and $(0.00314, 0.03908)$ mg/kg for the logit and probit models respectively. These models differered by only 8.7% from the Navarro-Silva's results.

The log-log model was significantly different with an $LC_{50} = 0.059$ mg/kg and 95% credible set of $(0.00436, 0.74670)$. Although the LC_{50} estimation is more than twice that of Navarro-Silva's, the broad credible set does contain Navarro-Silva's median lethal concentration.

5 Conclusion

This project demonstrated the use of bayesian logit, probit, and log-log models to reproduce the estimated median lethal concentraion (LC_{50}) of microencapsulated lambda-cyhalothrin (MELC) on brown recluse spiders (*Loxosceles intermedia*). Navarro-Silva published their estimation of $LC_{50} = 0.023$ mg/kg. The bayesian logit and probit models implemented here gave an estimation of $LC_{50} = 0.021$, very similar to the Navarro-Silva estimation. The log-log model was significantly different with an estimated $LC_{50} = 0.059$, but the Navarro-Silva estimation is still within the 95% credible set of $(0.00436, 0.74670)$. The log-log model should likely not be used for modeling mortality rates

These results can be used to inform methods for controlling brown recluse populations by ensuring no more chemicals than necessary are applied. This has both economic and environmental benefits by minimizing the about of microencapsulated lambda-cyhalothrin used.

It was interesting being able to reproduce the results of published researchers, using Bayesian techniques learned in this class. To further this exploration of bayesian methods, I would apply similar technqiues to the other insecticides Navarro-Silva experimented with. The time dimension could also be futher explored for fixed concentrations. Furthermore, I would explore using a slightly different strategy by using OpenBUGS to directly estimate LC_{50} by modeling the concentration given mortality rate, rather than using the "missing data" strategy.

6 References

Navarro-Silva, M. A., et al. "Chemical Control of Loxosceles Intermedia (Araneae: Sicariidae) with Pyrethroids: Field and Laboratory Evaluation." Journal of Economic Entomology, vol. 103, no. 1, Entomological Society of America, 2010, pp. 166–71, doi:10.1603/EC09092.