CIRM CENTRE INTERNATIONAL DE RENCONTRES MATHÉMATIQUES
SCIENTIFIC EVENTS

Analysis of Simulated Trap Counts Arising for Correlated and Biased Random Walks

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Outline

Insects' population density.

Methods to calculate an insects' population density.

Individual-based approach.

Correlated Random Walk and Biased Random Walk.

Insects' simulation with:

- One trap.
- Two traps.
- Three traps

Insects' population density

- Insects disperse from their habitat.
- Why is it important?

a) Environment:

- Crocus
- Sunflower,

b) Human:

- Food,
- Clothes,

Insects' population density

- Pest insects cause a lot of harm, therefore their density has to be closely monitored.

Methods to calculate an insects population density.

- Direct Method.
- Indirect Methods.

  Cumulative Trap Account (CTA).
- Trap benefit.

Individual-based approach.

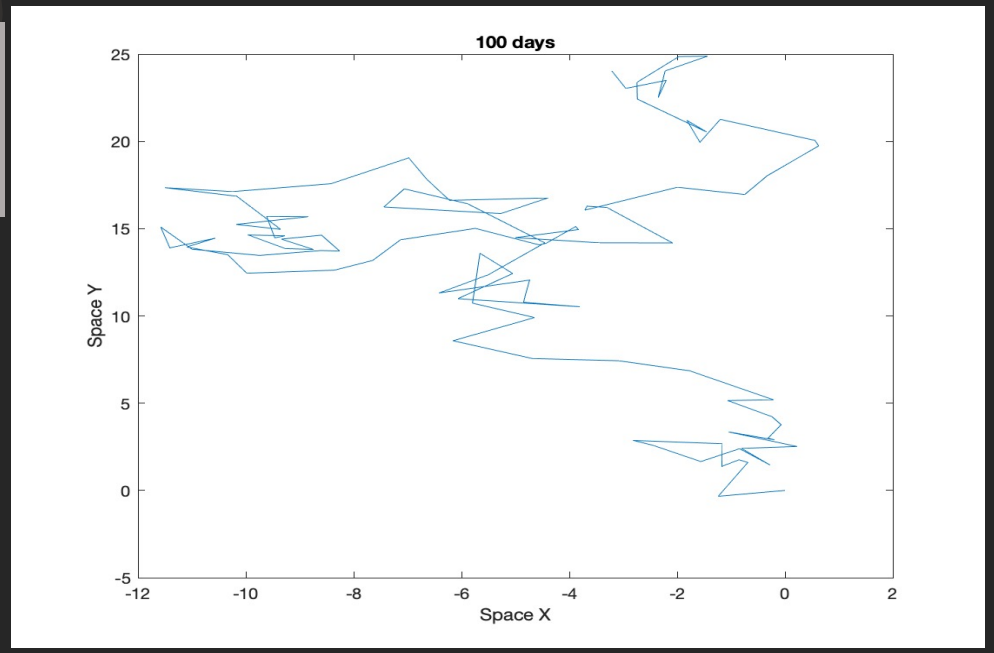
- The insect positions could be defined by [8]:

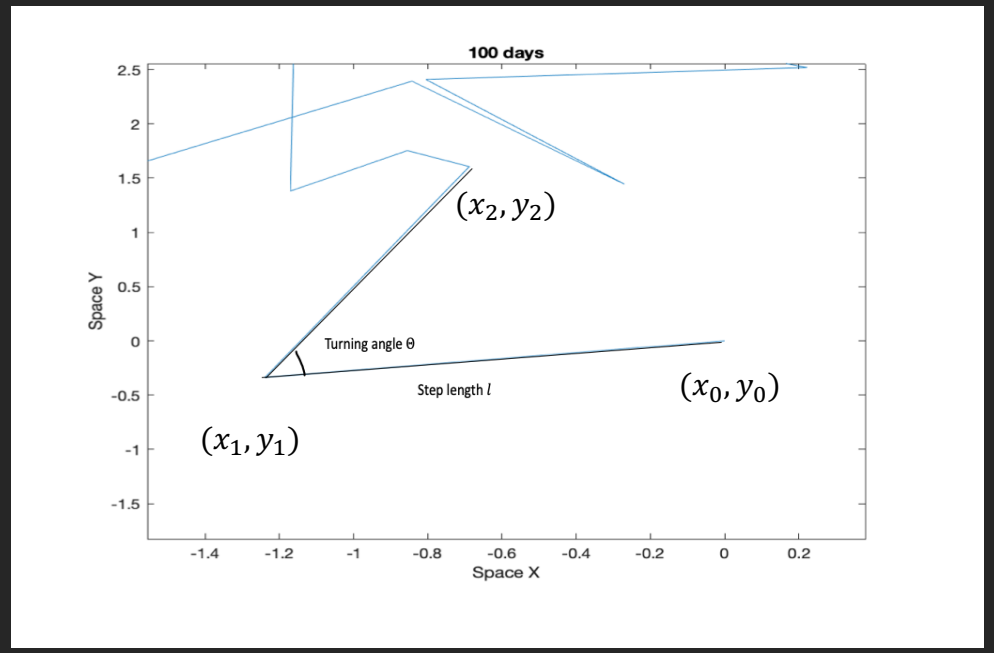
$$\boldsymbol{r}_i = \boldsymbol{r}(t_i) \qquad i = 0,1,2,3,\ldots$$

Where $\boldsymbol{r}$ insect's position and t is time.

- Trajectory movement baths are usually continuous curve. However, for the technical reasons to make easer to analysis the baths, people approximate the continues curve to the broken line.

- Note that the following models depend on the step length l and the turning angle Θ.





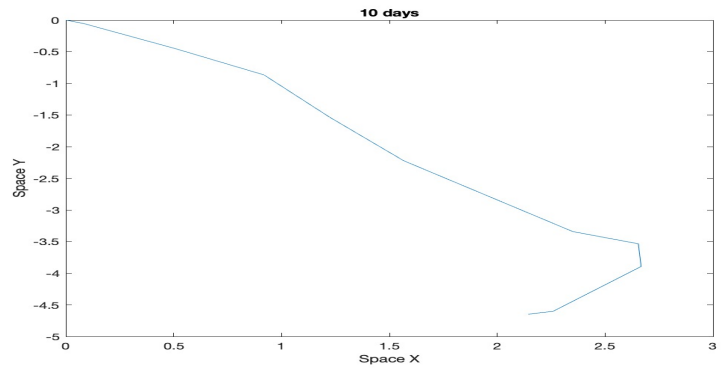
Correlated Random Walk (CRW)

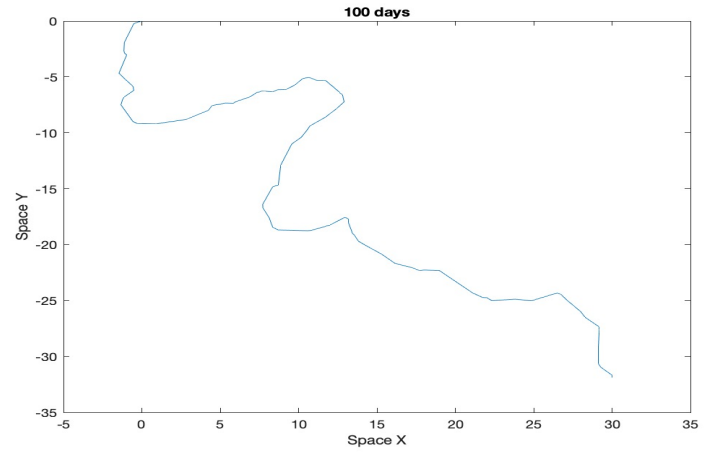
- We are going to define CRWs [9]:

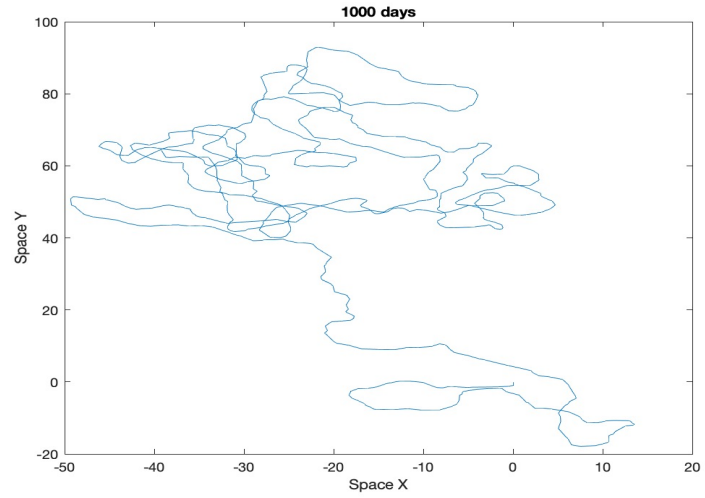
$$\lambda\,(l;\delta) = \frac{1}{\delta^2}\exp\left(-\frac{l^2}{2\delta^2}\right), \qquad 0 < l < 1$$

$$P(\Theta) = \frac{1}{p_0\sqrt{2\pi}}\exp\left(-\frac{\Theta^2}{2p_0^2}\right), \qquad -\pi < \Theta < \pi$$

where λ is the probability distribution for the step length l, P is the normal distribution for the turning angle Θ and p_0 which is the persistence parameter for the insect movement. Note that λ also describes insect distribution with scale parameter $\sqrt{2}\Theta$ and the turning angle in CRWs is not a uniform distribution over the circle.







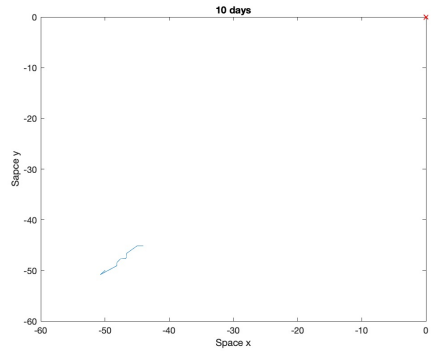
Biased Random Walk (BRW)

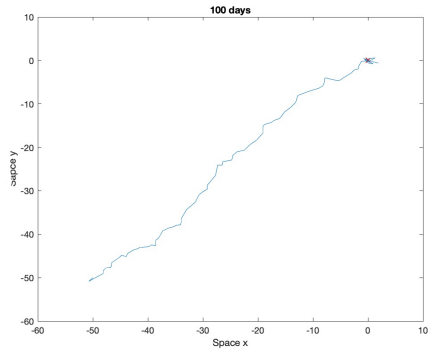
- We are going to define BRW :

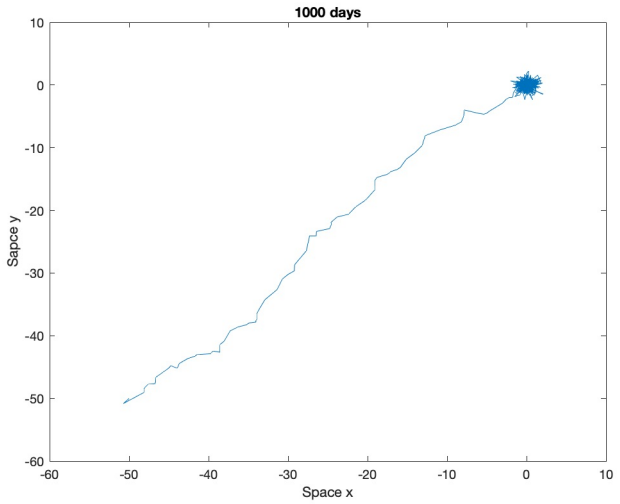
$$\lambda\,(l;\delta) = \frac{1}{\delta^2}\exp\left(-\frac{l^2}{2\delta^2}\right), \qquad 0 < l < 1$$

$$P(\Theta,\kappa) = \frac{1}{p_0\sqrt{2\pi}}\exp\left(-\frac{(\Theta-\kappa)^2}{2p_0^2}\right) \quad -\pi < \Theta < \pi$$

where λ is the probability distribution for the step length l, and it describes an insect's distribution with scale parameter $\sqrt{2}\delta$. P is the probability distribution for the turning angle Θ, p_0 which is the persistence parameter for the insect movement, κ is a trap position and it depends on the position of the insect and the light trap.

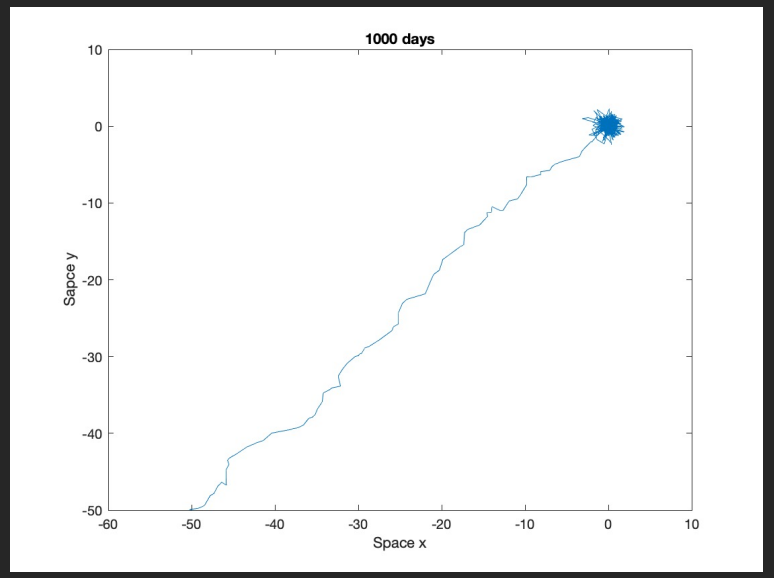


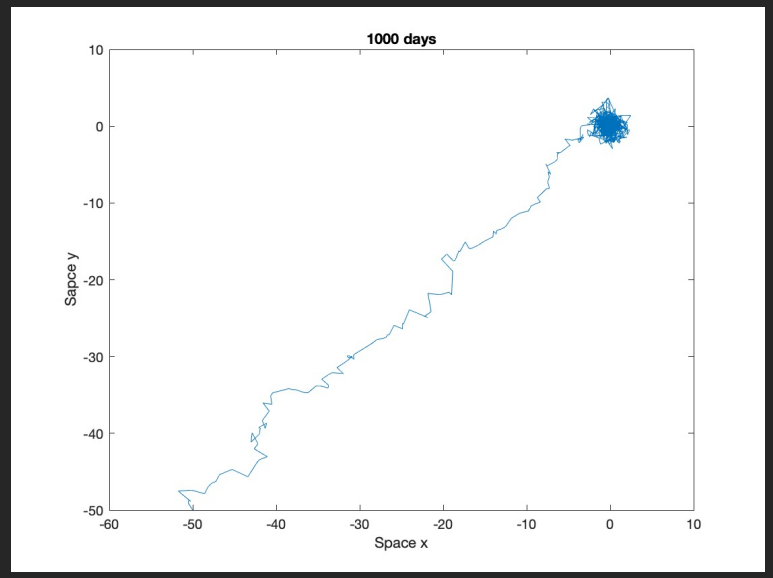


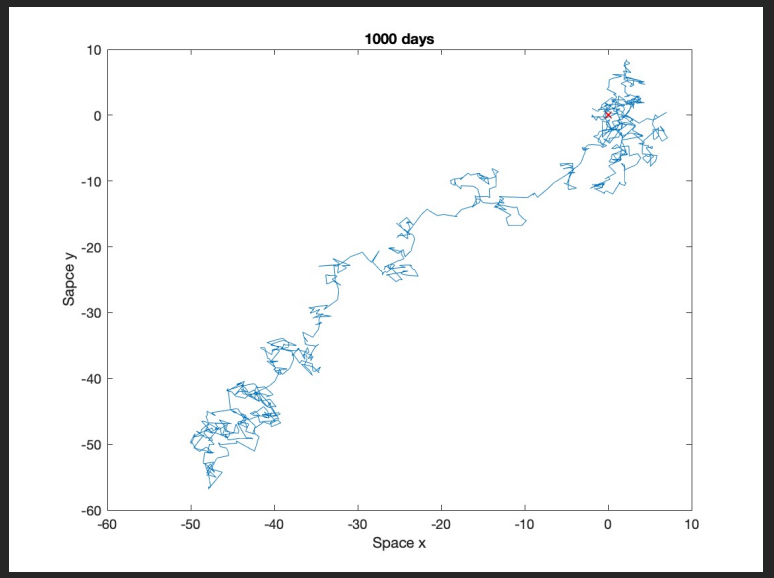


How p_0 affect on the movement

- The below figures show the insect simulation using BRW in the same time but the different value of p_0. From left to right $p_0 = 0.5, 1, 2$.



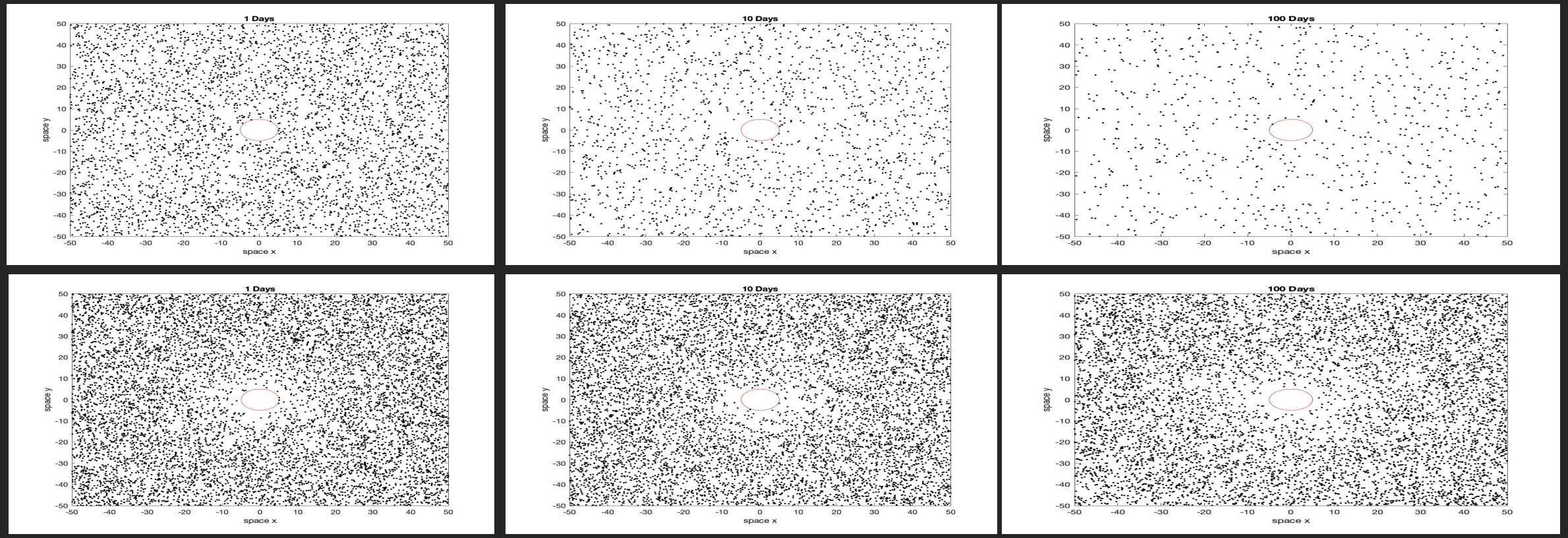




Insects' Simulation With One Trap In The Field

- We suppose that the insects simulate by using CRWs model. Also, they moved in a 50×50 square field, the insects' population is 10^4 and there is a circular trap with a radius of 5 in the centre of the field.
- Condition: $\sqrt{(x_i - X)^2 + (y_i - Y)^2} < R_l, \quad i = 0,1,2,3 \ldots.$

where $(x_i\,, y_i)$ is the insect's position, (X, Y) is the centre of the trap and R_l is the radius of the trap.

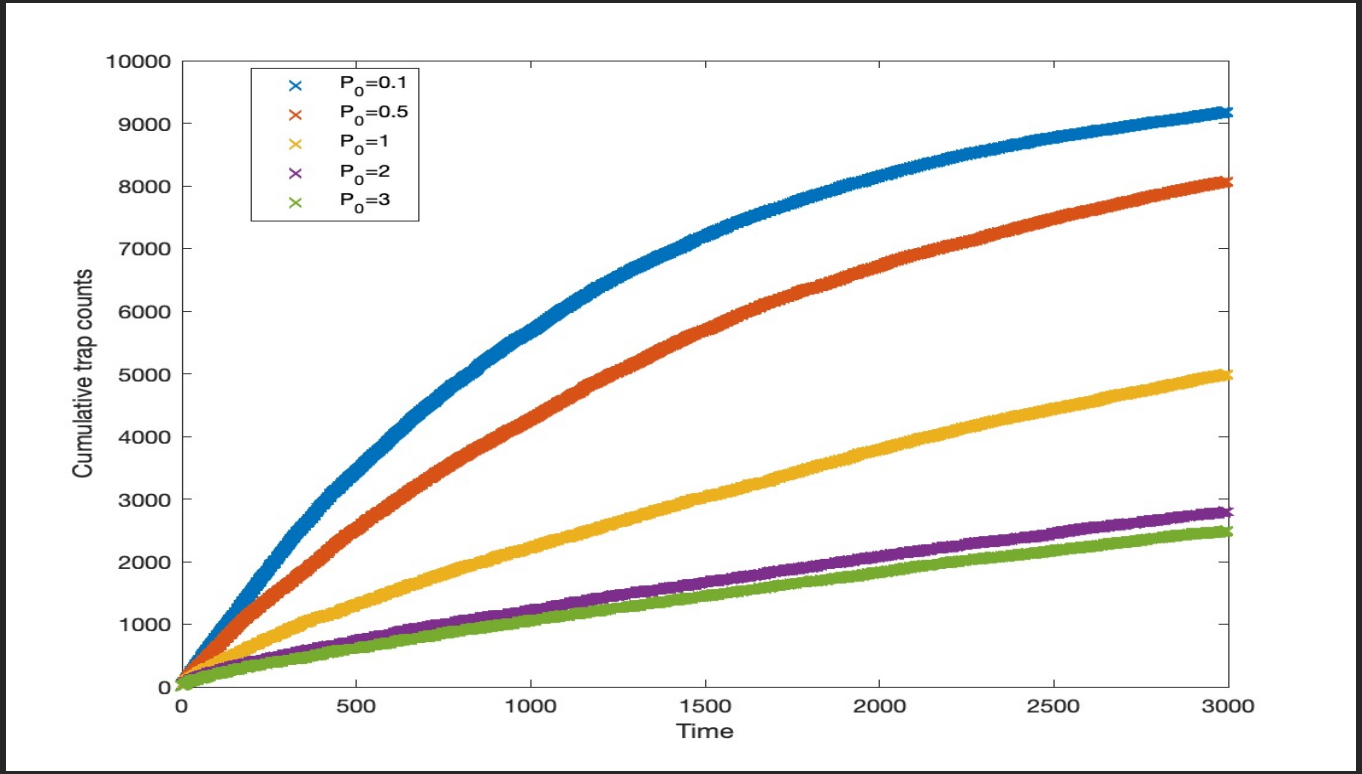


Insects' Simulation With One Trap In The Field

- To count the number of insects that are caught by the trap each day, we should create a sequence of cumulative trap counts. We will assume that the sum of all trap counts S_n for n days is [8]:

$$S_n = S(t_n) = \sum_{i=1}^{n} T_i \qquad i = 1,2,3, \ldots, n$$

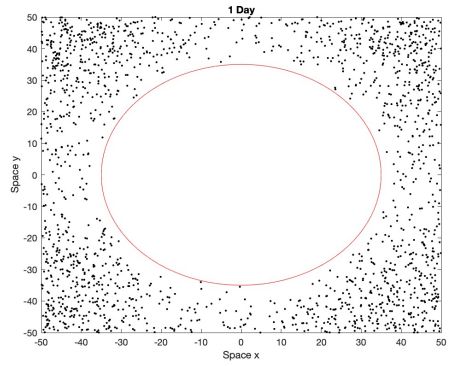
where T_i is the trap count from the first days to n days.

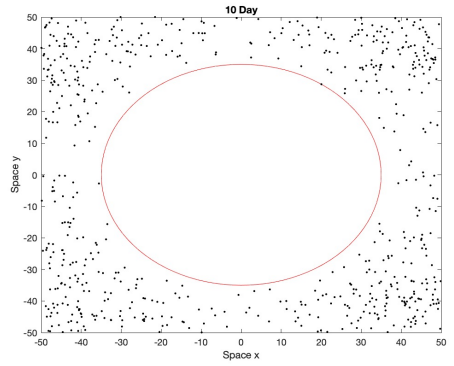


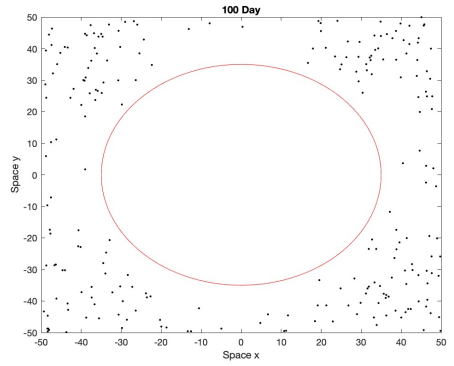
Insects' Simulation With One Trap In The Field Large Trap VS Attraction Trap

- We assume that the insects move in the field on the same size for the previous field.
- Large trap condition: $\sqrt{(x_i - X_l)^2 + (y_i - Y_l)^2} < R_{large}, \quad i = 0,1,2,3 \ldots.$

where $(x_i\,, y_i)$ is the insect's position, (X_l, Y_l) is the centre of the trap and $R_{larege} = 35$ is the radius of the trap.







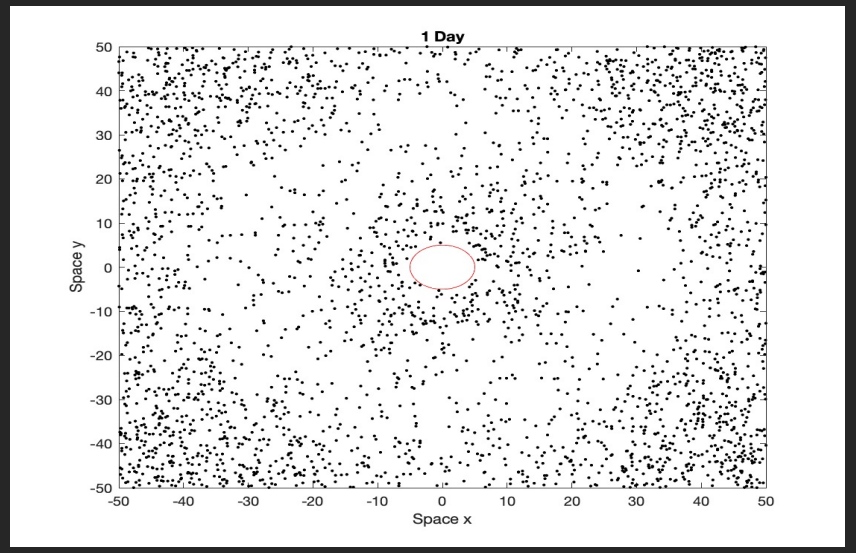
Insects' Simulation With One Trap In The Field
Large Trap VS Attraction Trap

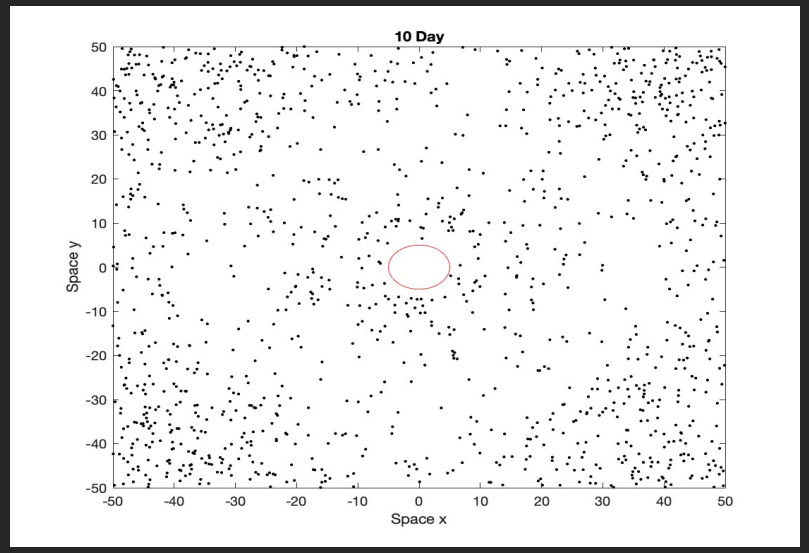
- We assume that the insects move in the field on the same size for the previous field.
- Attraction trap condition: $\sqrt{(x_i - X)^2 + (y_i - Y)^2} < R, \quad i = 0,1,2,3 \ldots.$

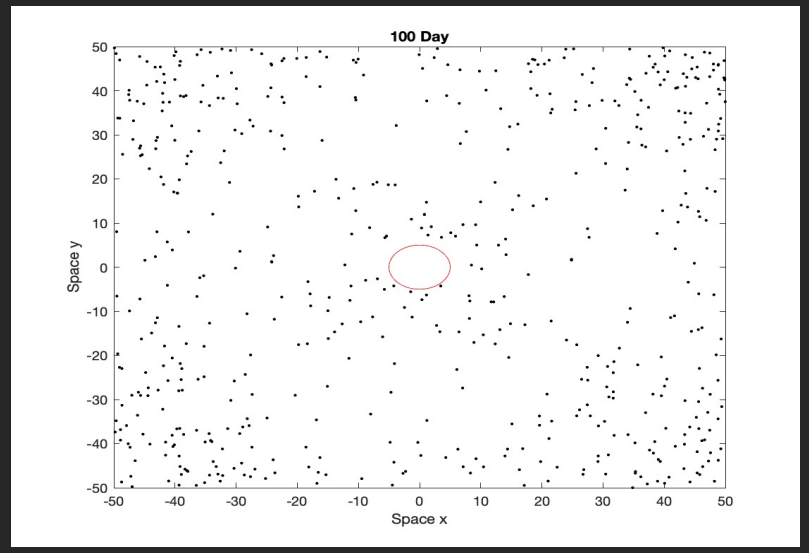
where $(x_i\,, y_i)$ is the insect's position, (X, Y) is the centre of the light trap and $\mathrm{R} = 5$ is the radius of the trap.

- Attraction condition: $\sqrt{(x_i - X_{Att})^2 + (y_i - Y_{Att})^2} < R_{Att}, \quad i = 0,1,2,3 \ldots.$

where $(x_i\,, y_i)$ is the insect's position, (X_{Att}, Y_{Att}) is the centre of the attraction light and $R_{Att} = 35$ is the radius of attraction.





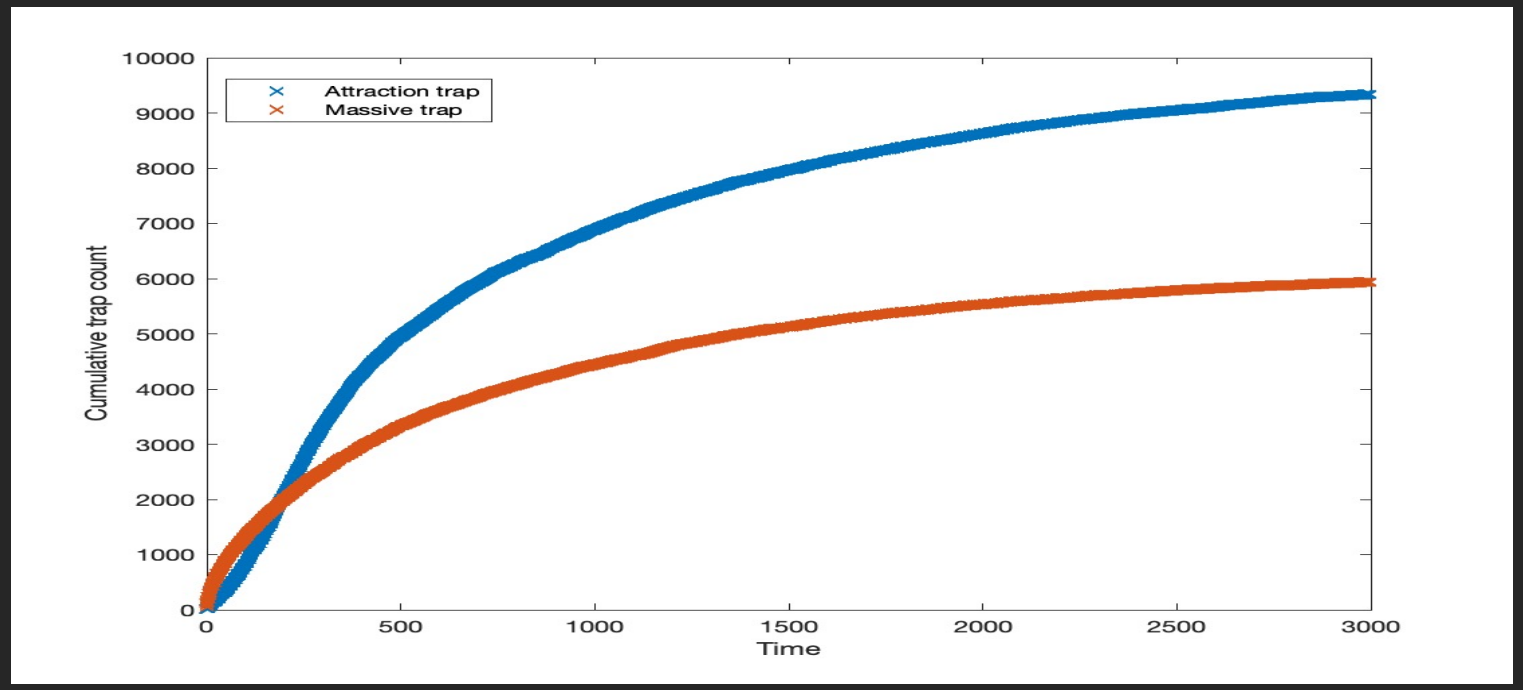


Insects' Simulation With One Trap In The Field
Large Trap VS Attraction Trap

- To count the number of insects that are caught by the large and attraction traps each day, we should create a sequence of cumulative trap counts for each of them. We will assume that the sum of all trap counts S_n for n days is [8]:

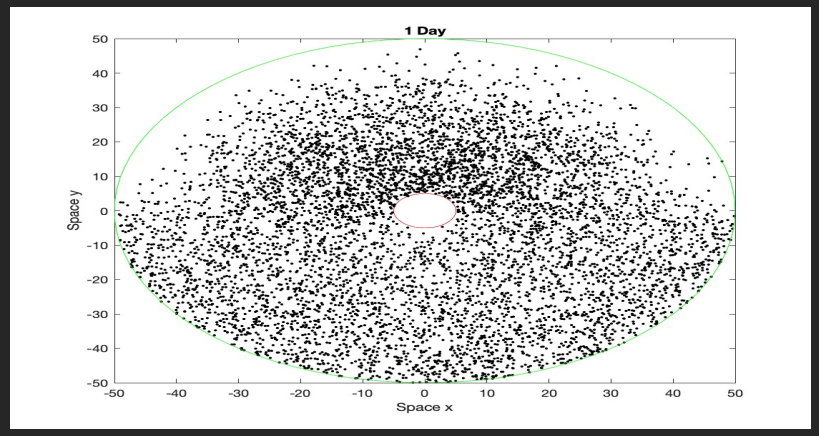
$$S_n = S(t_n) = \sum_{i=1}^{n} T_i \qquad i = 1,2,3, \ldots, n$$

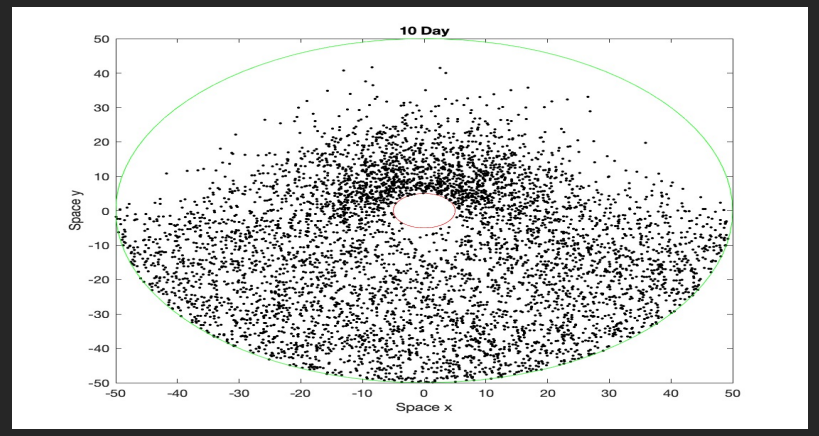
where T_i is the trap count from the first days to n days.

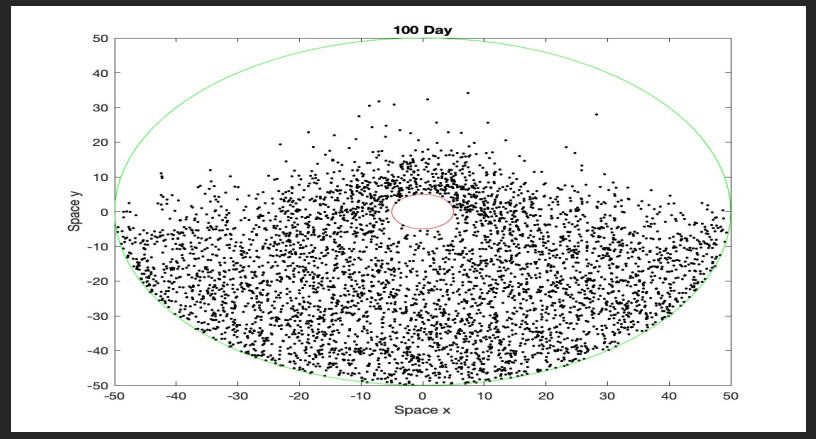


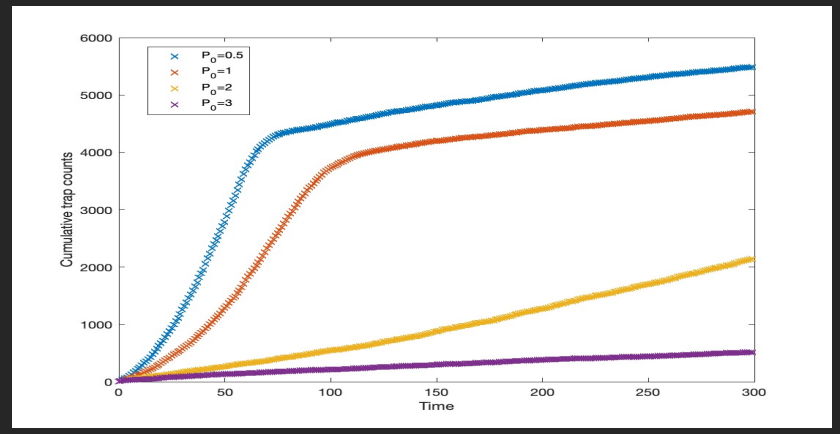
Insects' Simulation With One Trap In The Field Attraction From One Side

- We will consider that insects move in a circle field shape with a radius of 50 and the insect population is $8k$. A round light trap with a radius of $R_l = 5$ is installed in the centre of the field.



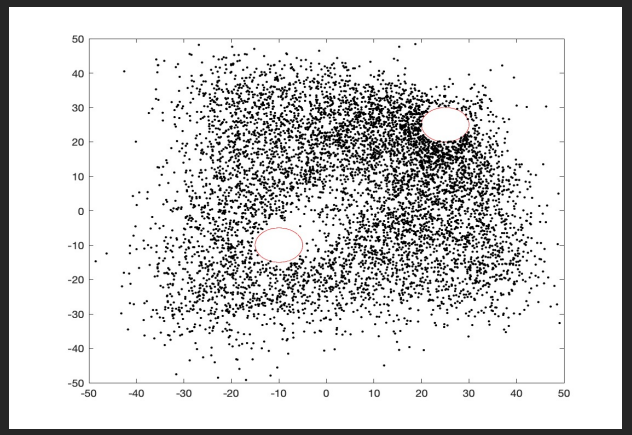


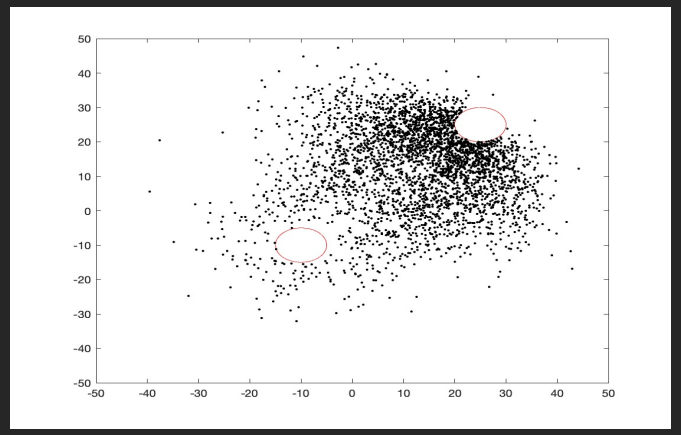


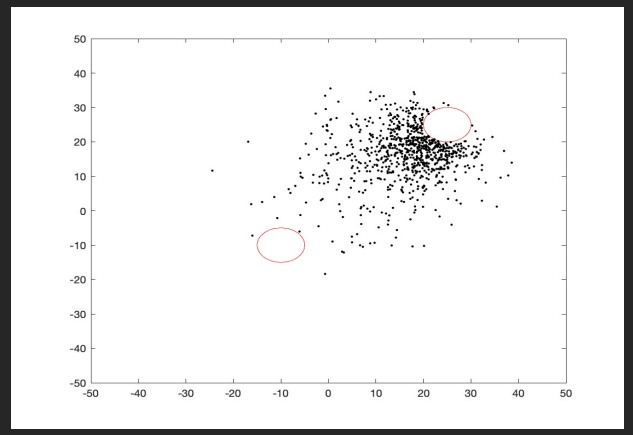


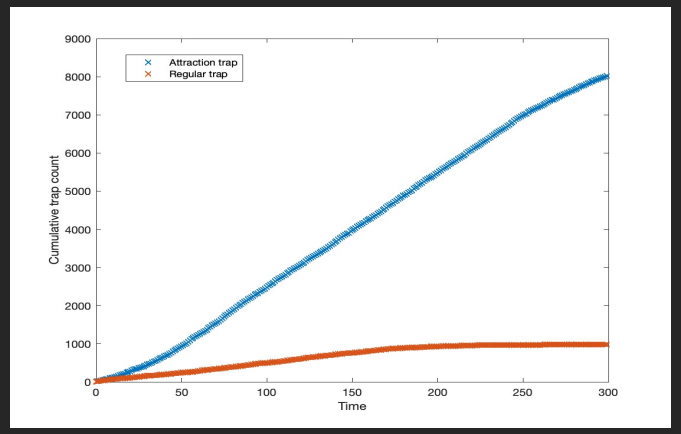
Insects' Simulation With Two Traps In The Field Attraction and Non-Attraction traps

- We suppose that the insects moved in a 50×50 square field, the insects' population is 10^4 and there are two circle traps with a radius 5 each installed in each field. The attraction trap position is $(25,25)$ and non-attraction trap position is $(-10,-10)$.



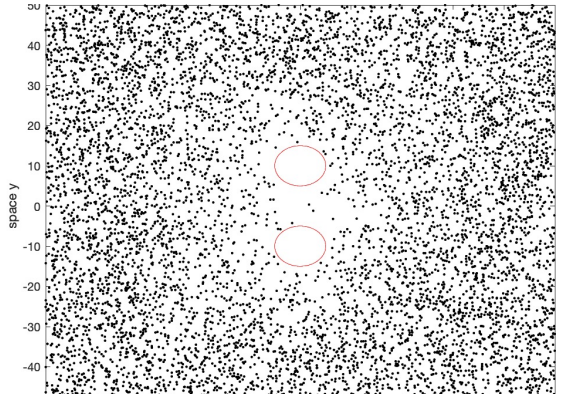


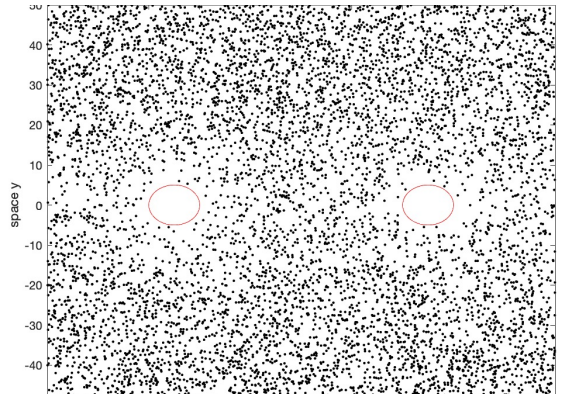


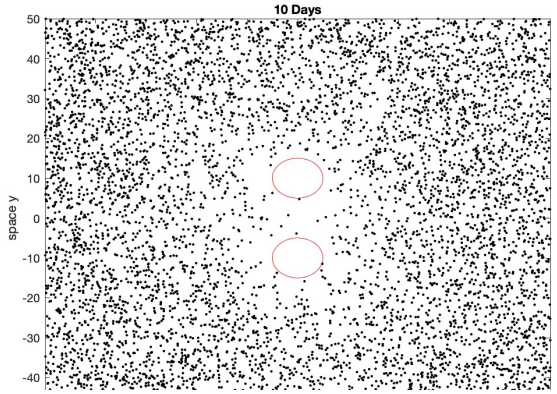


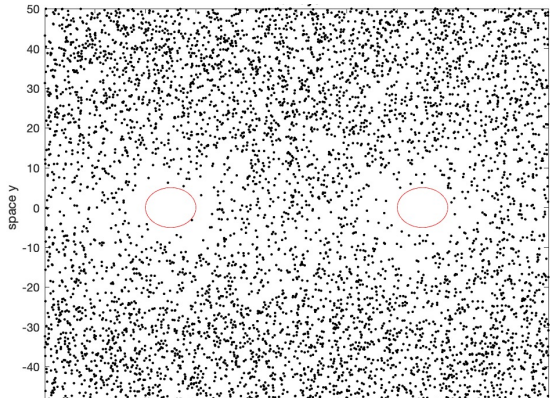
Insects’ Simulation With Two Traps In The Field
Catchment Area

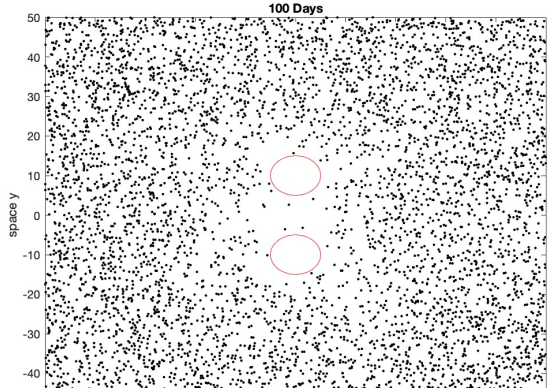
- We suppose that the insects moved in a 50×50 square field, the insects' population is 10^4 and there are two circle traps with a radius 5 each installed in each field. Note that both traps are not attraction traps.

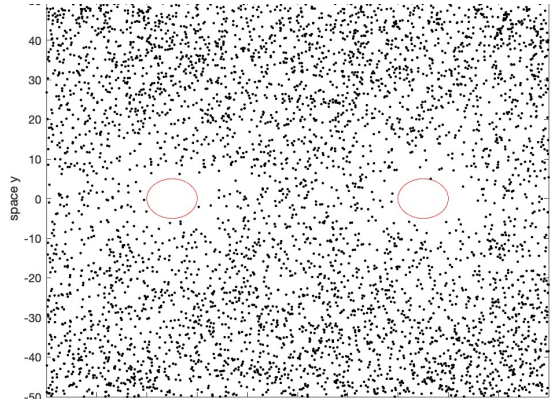






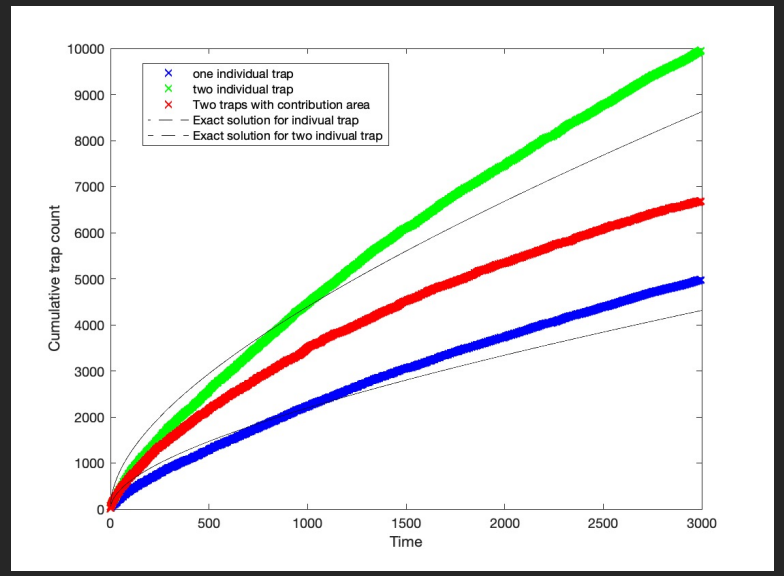


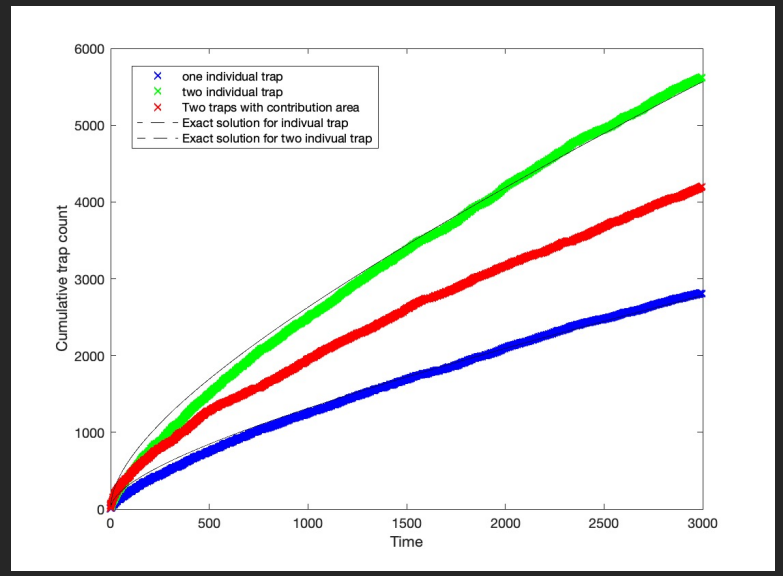


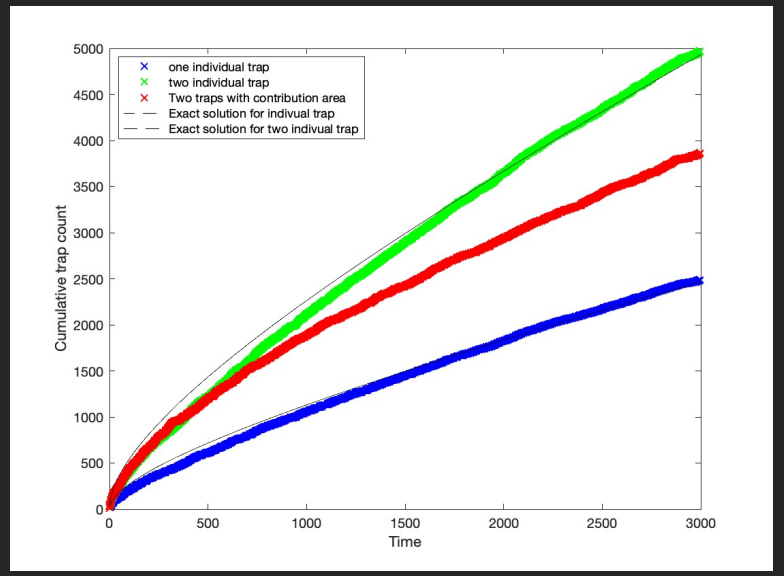


Insects' Simulation With Two Traps In The Field Catchment Area

- The Cumulative trap account for both cases (Catchment area and non-catchment area). From left to right $p_0 = 1,2,3$

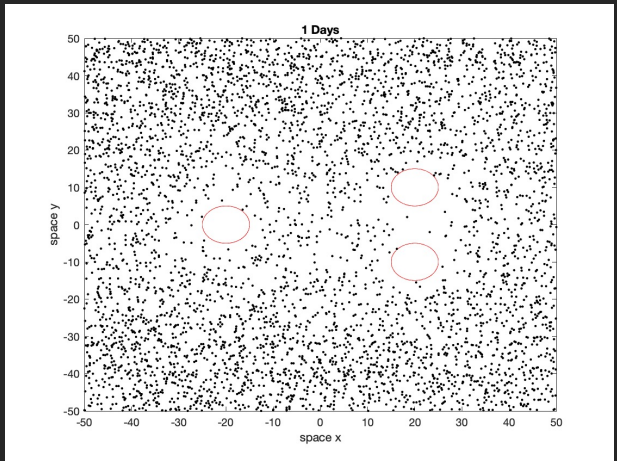


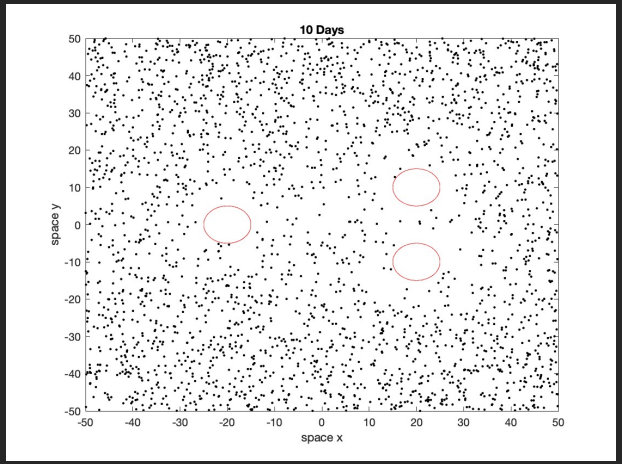


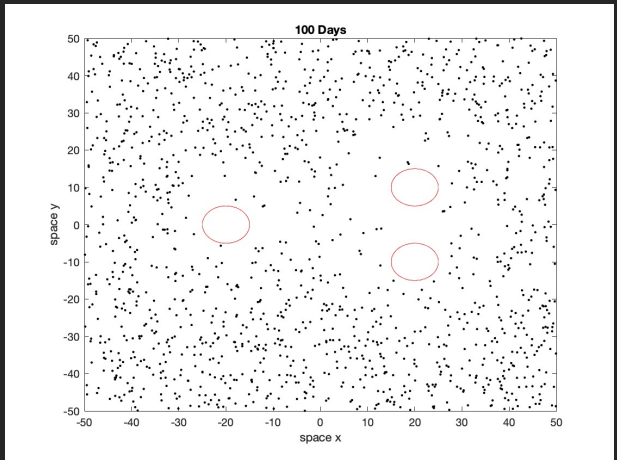


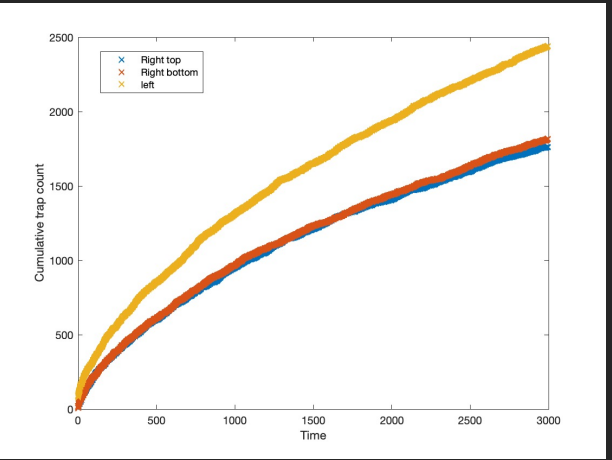
Insects' Simulation With Tree Traps In The Field.

- We suppose that the insects moved in a 50×50 square field, the insects' population is 10^4 and there are three circle traps with a radius 5 each installed in the field. Note that the traps are not attraction traps.









Conclusion

- The cumulative trap count affect by the value of persistence parameter p_0
- Attraction traps are more effective than large trap.
- The attraction trap is more effective than the non-attraction trap.
- The result for two traps without a catchment area has really good accuracy. However, the cumulative trap count for two traps with overlap area is less than when we have two traps without a catchment area.
- The cumulative trap count result is affected by the trap positions.
- The Attraction shape and the trap shape also will affect on the cumulative trap account.


Thank you for listening.

Reference:"

[1] https://backyardprime.com/how-to-grow-and-care-for-crocus-flower/

[2] https://www.dobies.co.uk/flowers/flower-seeds/all/sunflower-seeds---summer-long-mixed_421127

[3] https://www.bbc.co.uk/news/science-environment-53029218

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[6] https://www.britannica.com/plant/date-palm

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[9] Ahmed, D.A.; Petrovskii, S.V. Analysing the impact of trap shape and movement behaviour of ground-dwelling arthropods on trap efficiency. *Methods in Ecology and Evolution* **2019**, *10*, 1246–1264.