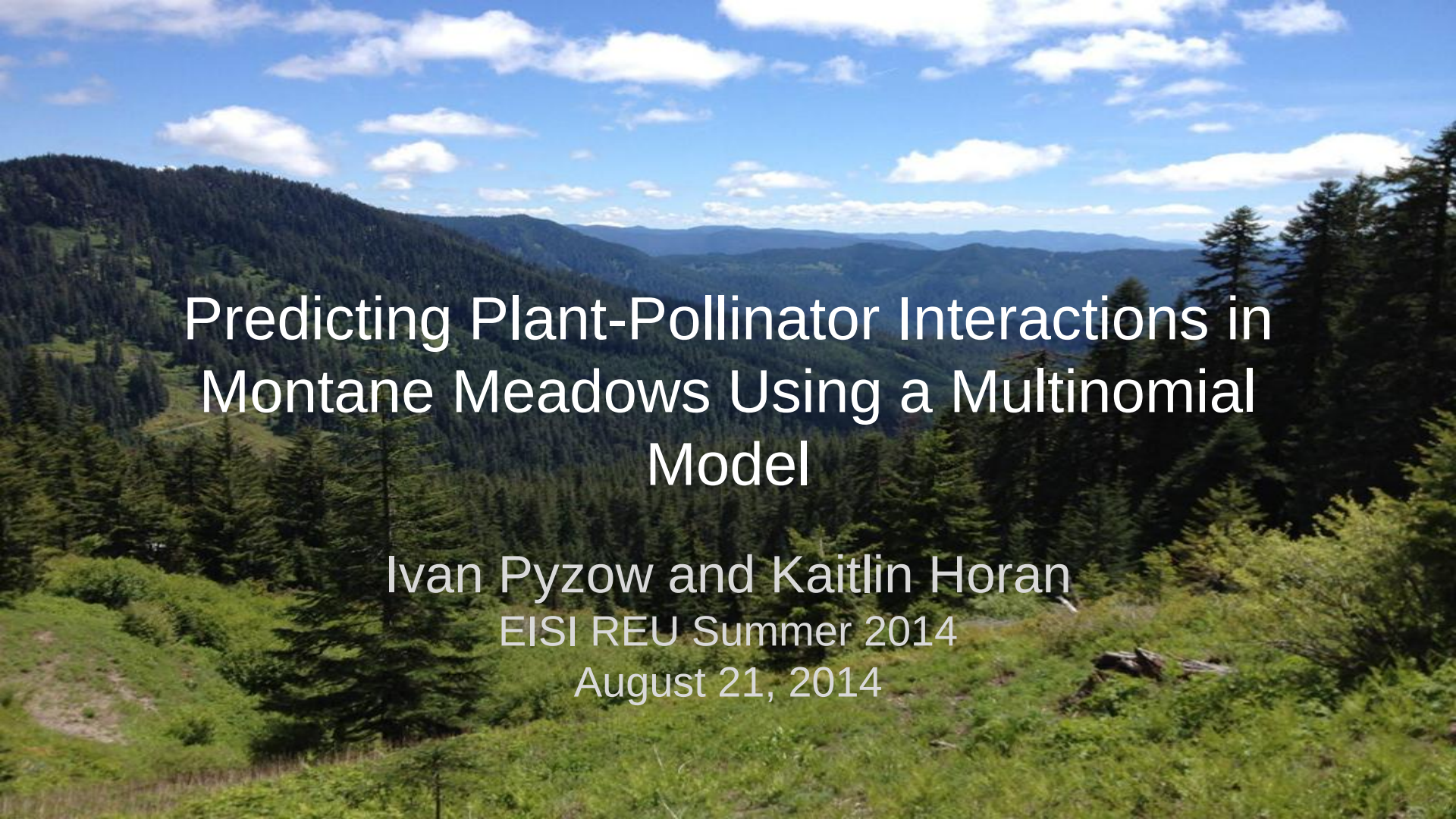


Predicting Plant-Pollinator Interactions in Montane Meadows Using a Multinomial Model

Ivan Pyzow and Kaitlin Horan

EISI REU Summer 2014

August 21, 2014

Definitions

pollinator's preference (for a flower): a value from 0 to 1 that quantifies the level of interactions with a flower, independent of the flower's relative abundance. In other words, we use preference to refer to all factors that influence flower selection besides frequency-dependence, which might be the nectar resource of the flower or an innate bias by the pollinator.

pollinator's preference list: a list of a pollinator's preferences for different flowers, scaled so that the list sums to 1.

Our Questions

1) Do the pollinators in this study exhibit flower selection strategies that are strictly frequency-dependent?

2) For each pollinator, how accurately does our optimized preferences list predict the observed interactions?

Our Hypotheses

1) We anticipate that pollinators do not exhibit a strictly frequency-dependent flower selection strategy.

2) We anticipate that our optimized preference list will return p-values greater than 0.95 when using a test of goodness-of-fit.

Pollinator	**Description**	**Number of Sightings** (Note this is different from the total number of interactions as the same pollinator might have had multiple interactions)
Apis mellifera	Social bee	4101
Bombus mixtus	Social bee	2835
Epicauta puncticollis	Beetle	1534
Bombus bifarius	Social bee	945
Muscoid genus 3	Fly	731
Bombylius major	Beefly	677
Eristalis hirtus	Syrphid	572
Coccinella septempunctata	Ladybird	459

Our Multinomial Model

$$L(d_1, d_2, ..., d_n) = \prod_{j=1}^{m} c_j \left(\prod_{i=1}^{n} \lambda_{ij}^{b_{ij}} \right)$$

where

m = number of meadow-watch-years

n = number of flower species

a_{ij} = abundance of flower i on meadow-watch-year j

b_{ij} = number of interactions between pollinator p and flower i on meadow-watch-year j

d_i = desirability of flower i for pollinator p

$$\lambda_{ij} = \frac{d_i a_{ij}}{\sum_{k=1}^{n} d_k a_{kj}}$$

$$c_j = \frac{\left(\sum_{h=1}^{n} b_{hj} \right)!}{\prod_{h=1}^{n} \left(b_{hj}! \right)}$$

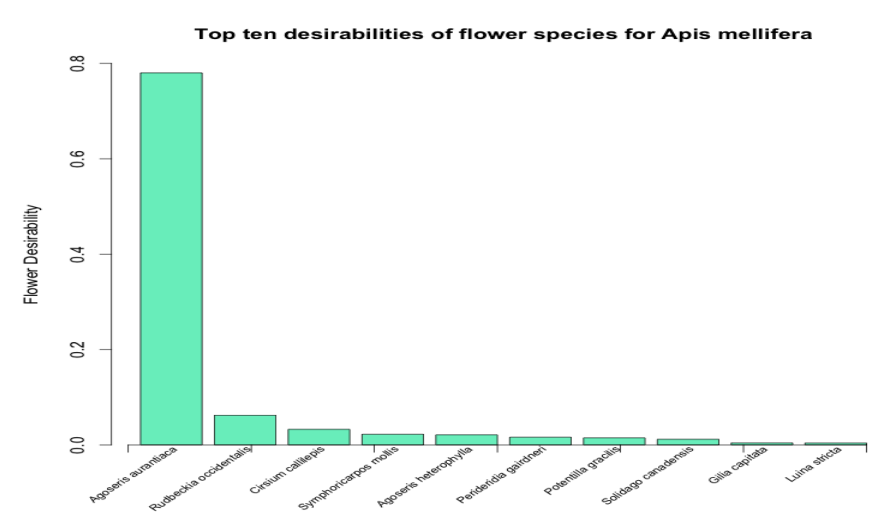
Maximizing the Likelihood Function

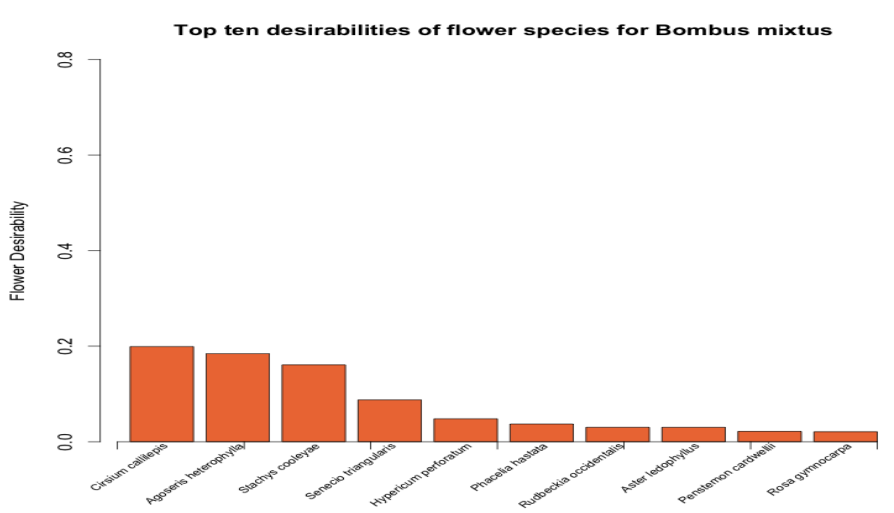
To generate our optimized preferences lists:

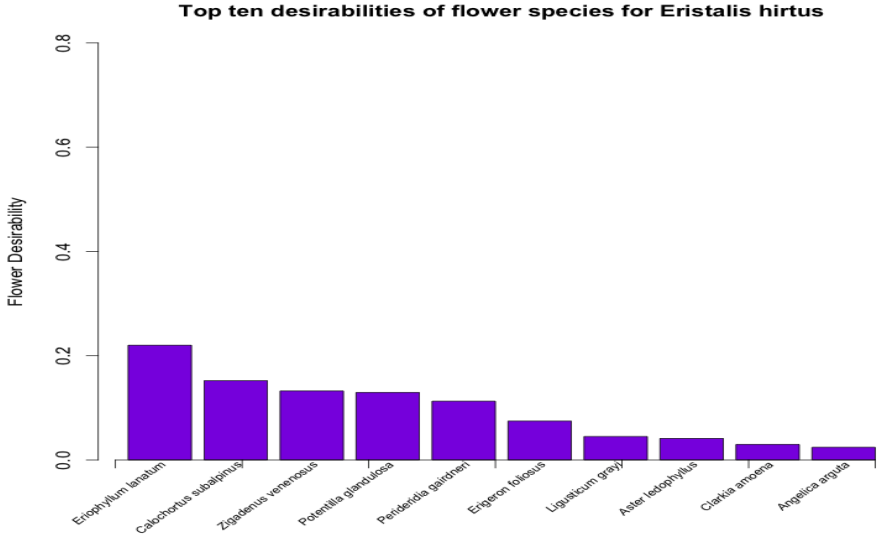
- input flower abundances and number of interactions by a given pollinator for each flower species
- minimize negative log likelihood
- output preference list

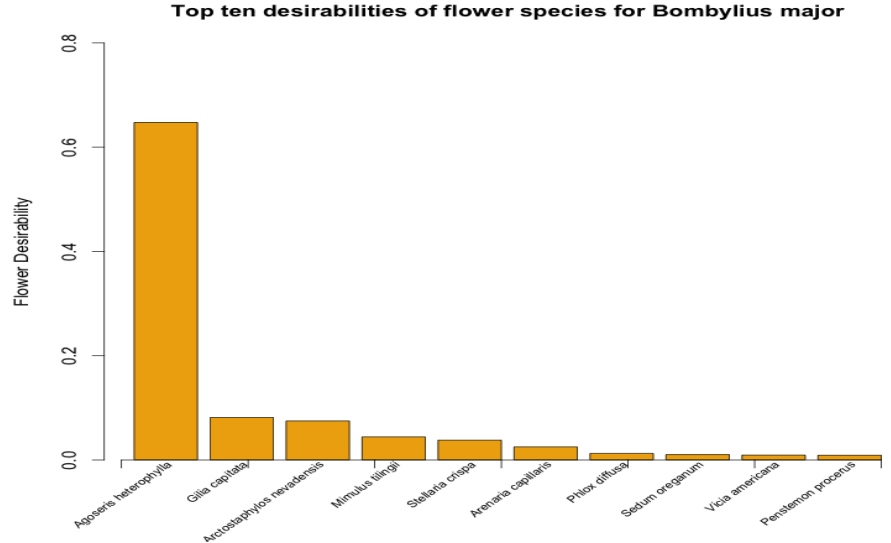
To calculate expected interactions:

- input flower abundances and pollinator preferences list


Top ten desirabilities of flower species for Apis mellifera
Flower Desirability
0.0
0.2
0.4
0.6
0.8
Agoseris aurantiaca
Rudbeckia occidentalis
Cirsium callilepis
Symphoricarpos mollis
Agoseris heterophylla
Peridendia gairdneri
Potentilla gracilis
Solidago canadensis
Gilia capitata
Luina stricta


Top ten desirabilities of flower species for Bombus mixtus
Flower Desirability
0.0
0.2
0.4
0.6
0.8
Cirsium callilepis
Agoseris heterophylla
Stachys cooleyae
Senecio triangularis
Hypericum perforatum
Phacelia hastata
Rudbeckia occidentalis
Aster ledophyllus
Penstemon cardwellii
Rosa gymnocarpa


Top ten desirabilities of flower species for Eristalis hirtus
Flower Desirability
0.0
0.2
0.4
0.6
0.8
Eriophyllum lanatum
Calochortus subalpinus
Zigadenus venenosus
Potentilla glandulosa
Peridendia gairdneri
Erigeron foliosus
Ligusticum grayi
Aster ledophyllus
Clarkia amoena
Angelica arguta


Top ten desirabilities of flower species for Bombylius major
Flower Desirability
0.0
0.2
0.4
0.6
0.8
Agoseris heterophylla
Gilia capitata
Arctostaphylos nevadensis
Mimulus tilingii
Stellaria crispa
Arenaria capillaris
Phlox diffusa
Sedum oreganum
Vicia americana
Penstemon procerus

The Five Tests

For each test, we predict interactions and then test how close the expected interactions are to the observed interactions.

1) Chi-squared with uniform preferences list for each watch-year
2) Chi-squared with uniform preferences list for all three years

3) Chi-squared with optimized preferences list for each watch-year
4) Chi-squared with optimized preferences list for all three years

5) Likelihood ratio test with uniform preferences list and optimized preferences list for all three years

Tests 1 and 2

1. Compares interactions predicted by uniform preferences list to observed interactions for each watch-year:

We reject the uniform preference list for all four insects.

2. Compares interactions predicted by uniform preferences list to observed interactions for all 3 years:

Again, we reject the uniform preference list for all four insects.

Test 3

3. Compares optimized preferences list for each watch-year.

Most watch-years are rejected, except for Eristalis hirtus.

APIS MELLIFERA

Watch-Year	p-value
2011 1	0.108
2011 2	0.527
2011 3	0
2011 4	0
2011 5	0
2011 6	0
2012 1	0.043
2012 2	0
2012 3	0
2012 4	0
2012 5	0
2013 1	0.947
2013 2	0
2013 3	0
2013 4	0
2013 5	0
2013 6	0
2013 7	0.044

BOMBUS MIXTUS

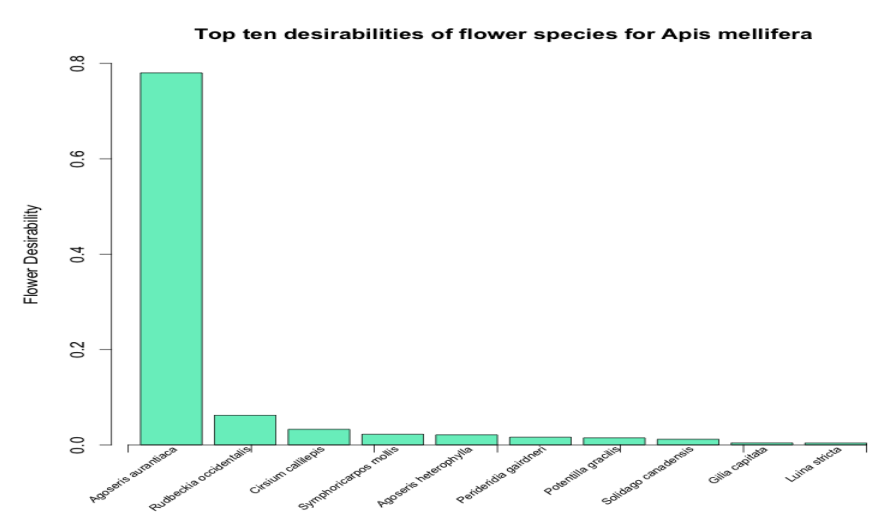
Watch-Year	p-value
2011 1	0
2011 2	0
2011 3	0
2011 4	0
2011 5	0
2011 6	0.007
2012 1	0
2012 2	0
2012 3	0
2012 4	0
2012 5	0.001
2013 1	0
2013 2	0
2013 3	0
2013 4	0
2013 5	0
2013 6	0
2013 7	0.07

BOMBYLIUS MAJOR

Watch-Year	p-value
2011 1	0
2011 2	0
2011 3	0
2012 1	0
2012 2	0
2012 5	1
2013 1	0
2013 2	1
2013 3	0.994

ERISTALIS HIRTUS

Watch-Year	p-value
2011 2	0
2011 3	0
2011 4	0
2011 5	0.762
2011 6	0.131
2012 1	0.974
2012 2	0
2012 3	1
2012 4	0.639
2013 7	0.986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Potentilla gracilis
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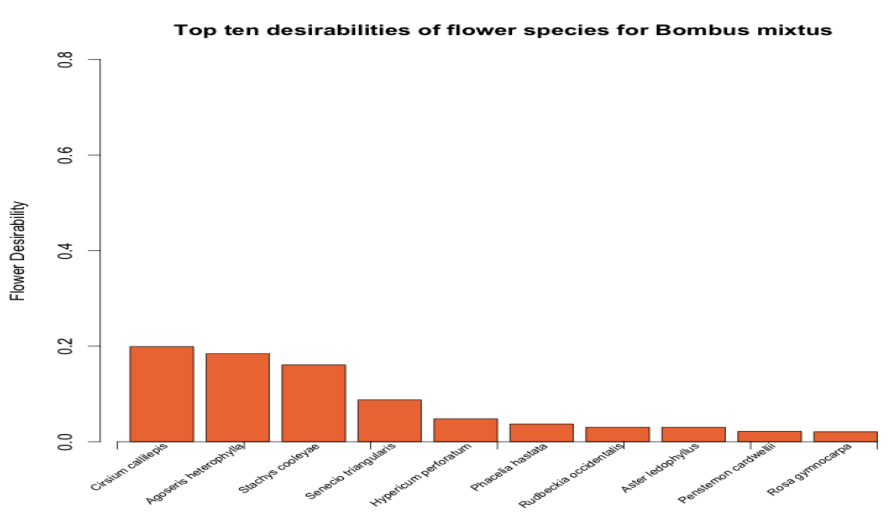
Gilia capitata
Luina stricta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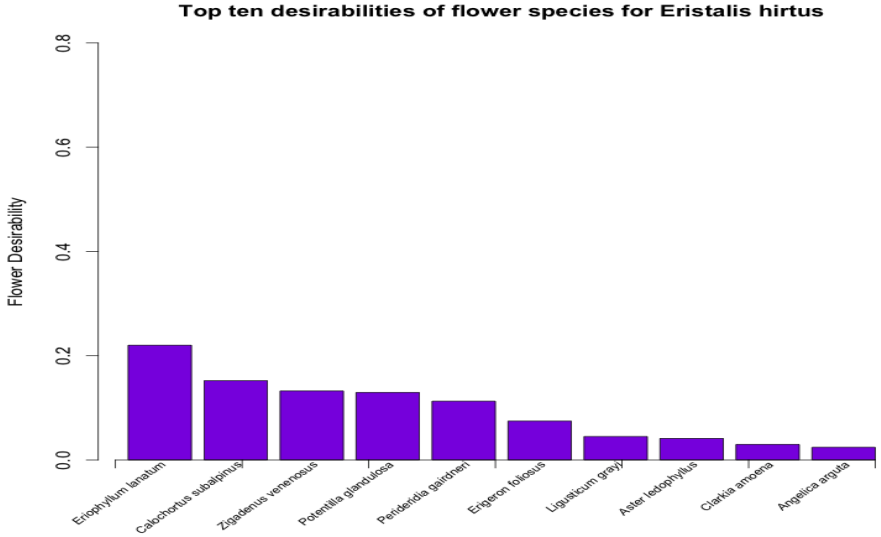
Top ten desirabilities of flower species for Eristalis hirtus
Flower Desirability
0.0
0.2
0.4
0.6
0.8
Eriophyllum lanatum
Calochortus subalpinus
Zigadenus venenosus
Potentilla glandulosa
Peridendia gairdneri
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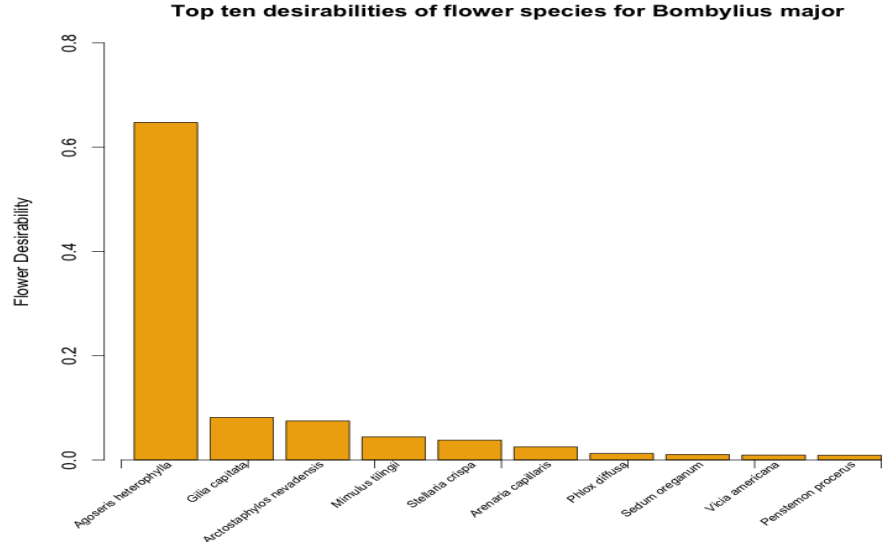
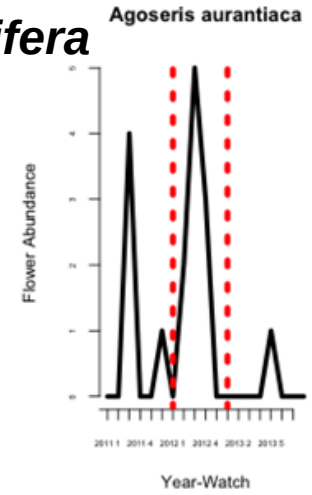
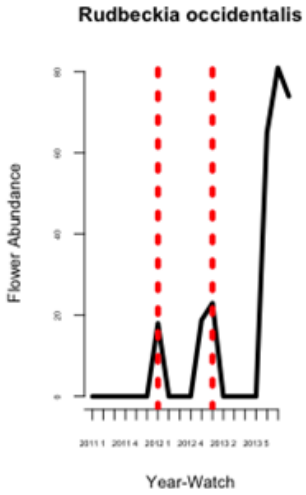
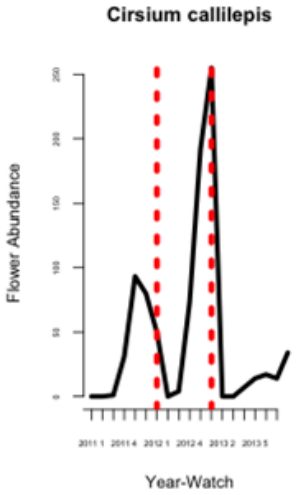
Aster ledophyllus
Clarkia amoena
Angelica arguta

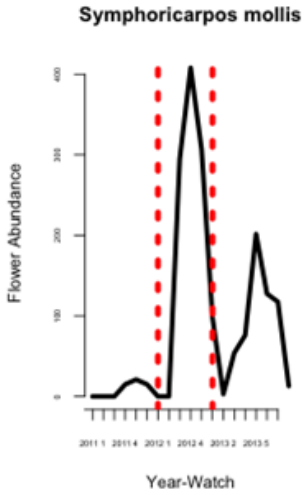

Top ten desirabilities of flower species for Bombylius major
Flower Desirability
0.0
0.2
0.4
0.6
0.8
Agoseris heterophylla
Gilia capitata
Arctostaphylos nevadensis
Mimulus tilingii
Stellaria crispa
Arenaria capillaris
Phlox diffusa
Sedum oreganum
Vicia americana
Penstemon procerus

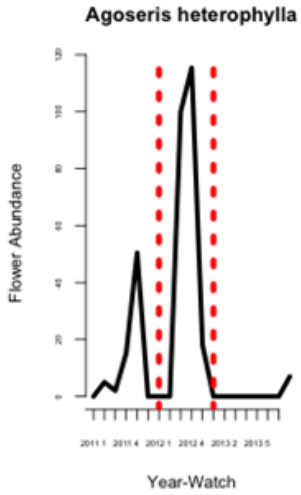
Apis mellifera

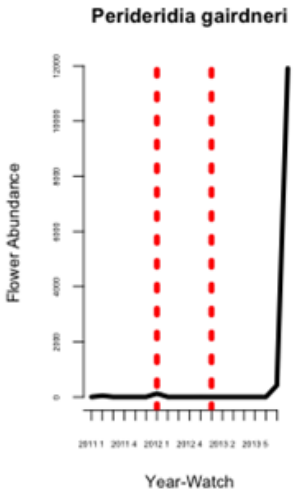


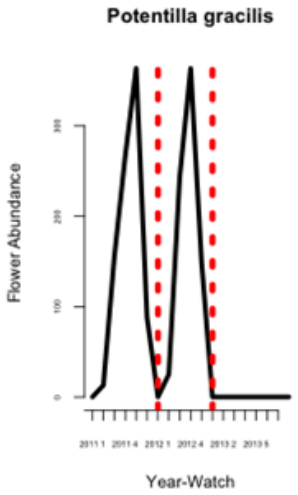


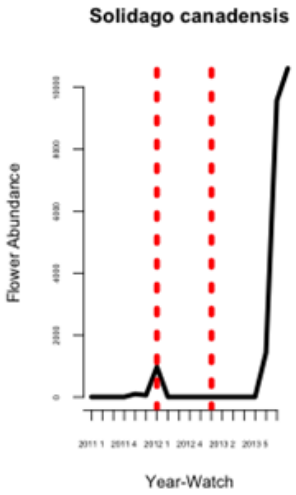


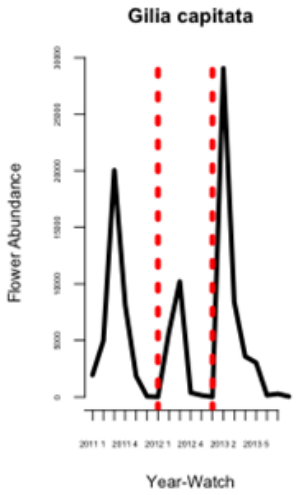


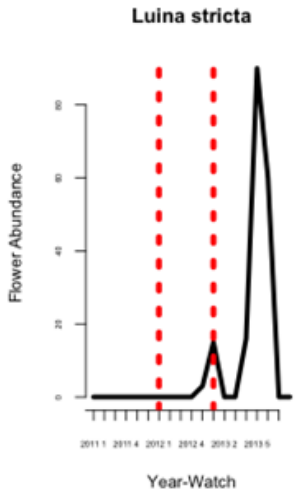




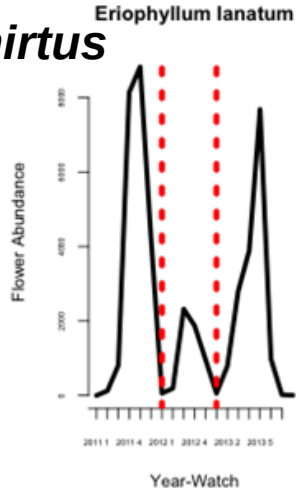


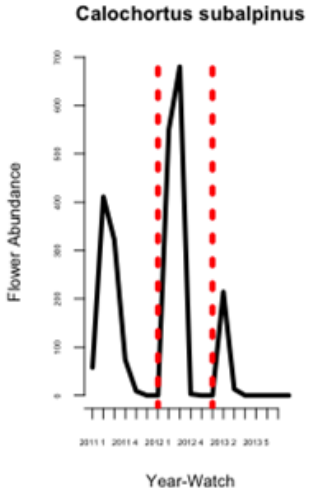


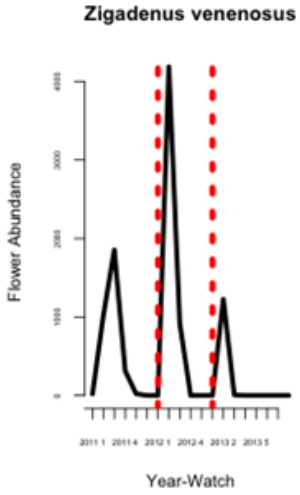


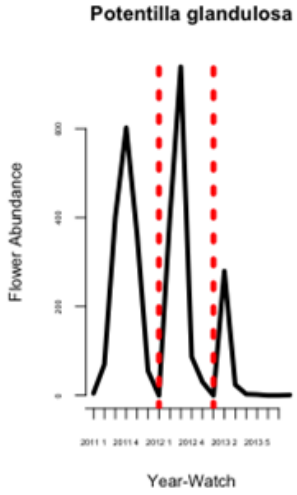


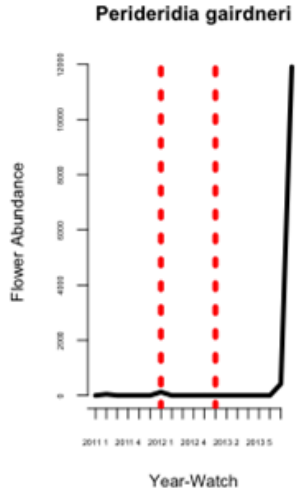
Eristalis hirtus

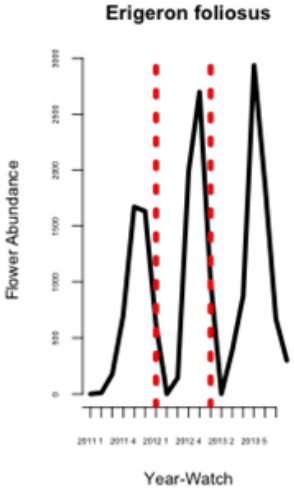


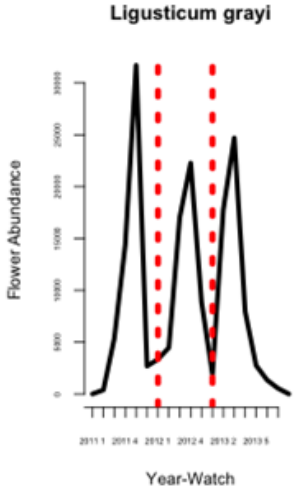


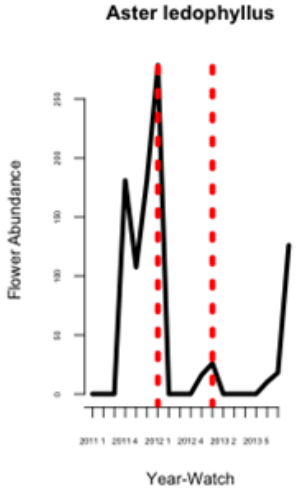


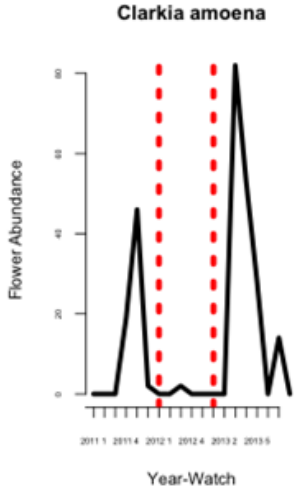


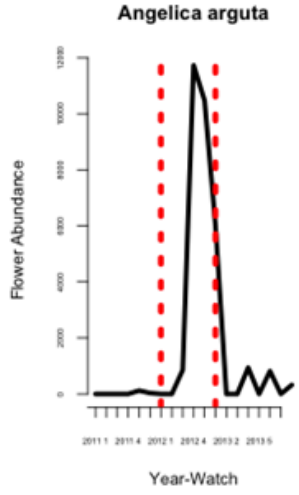








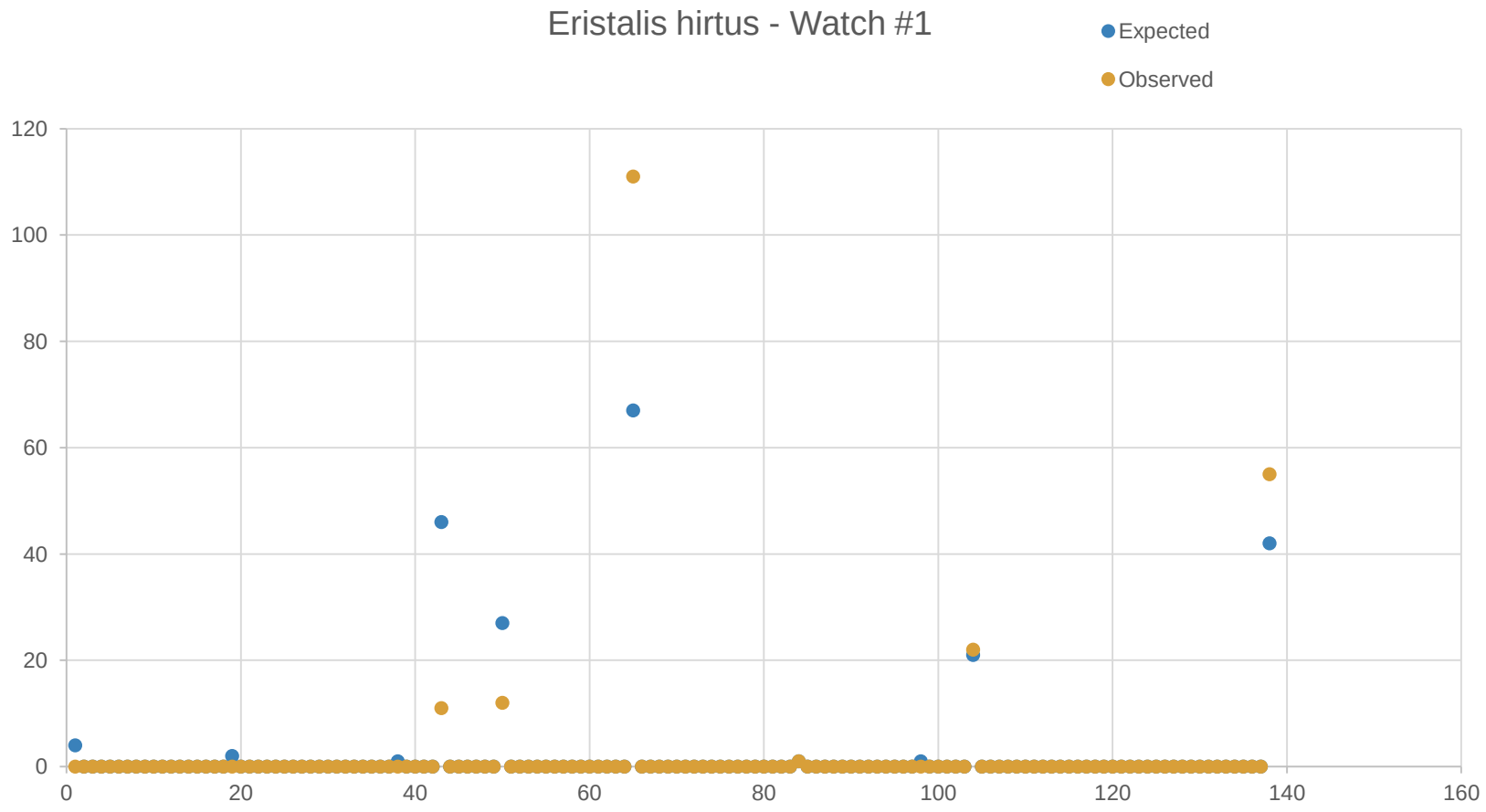


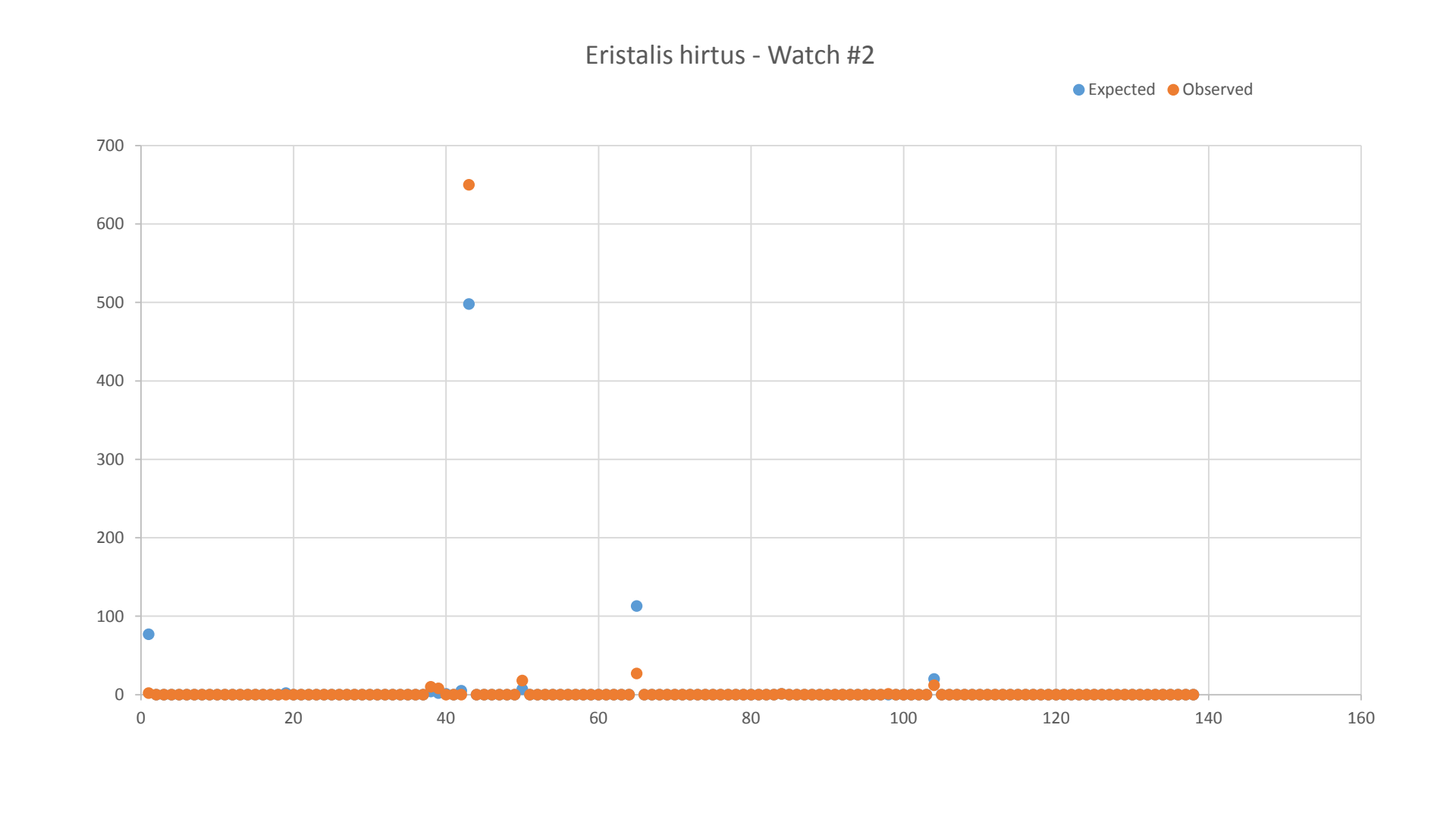


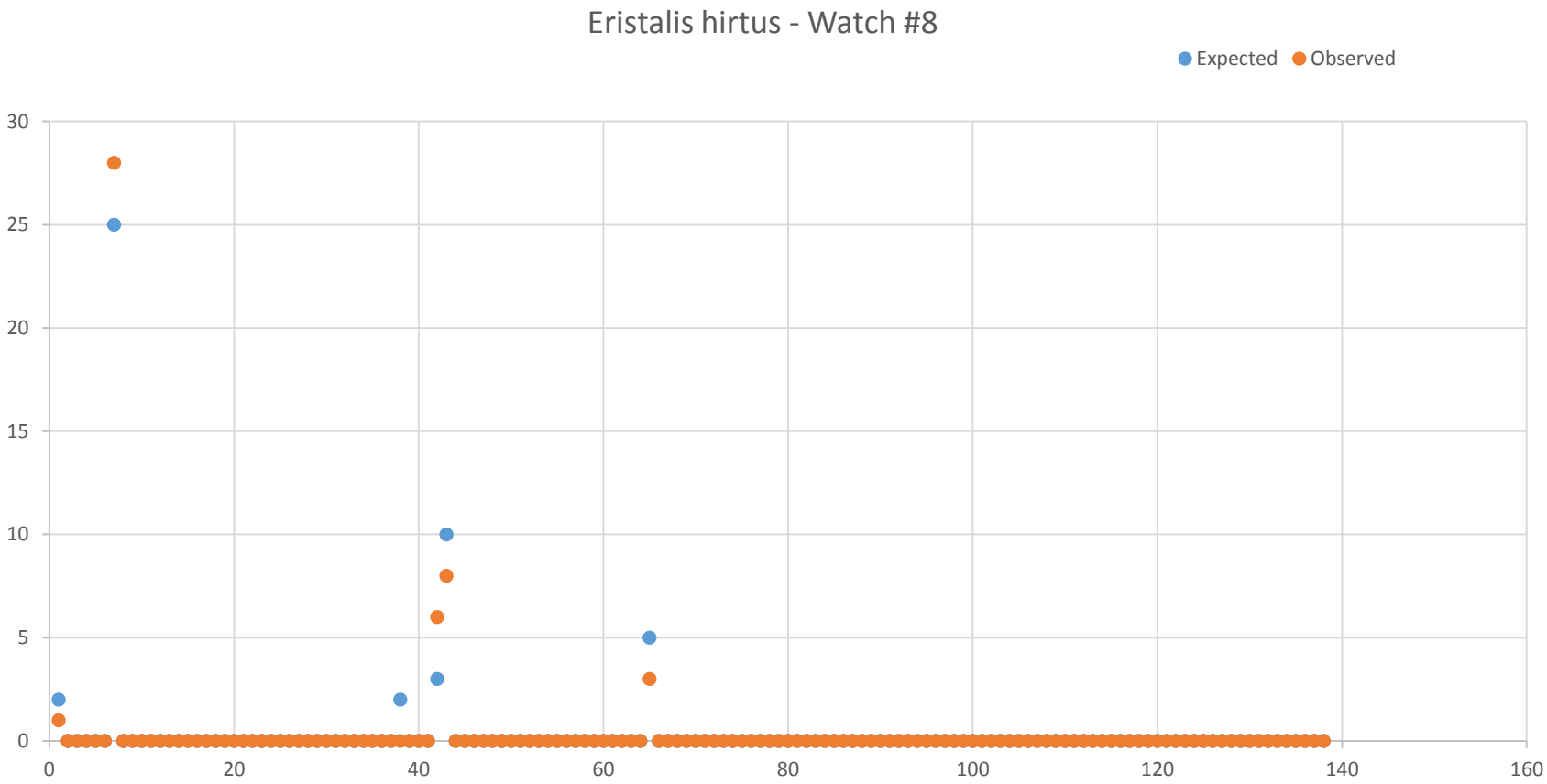
Test 4

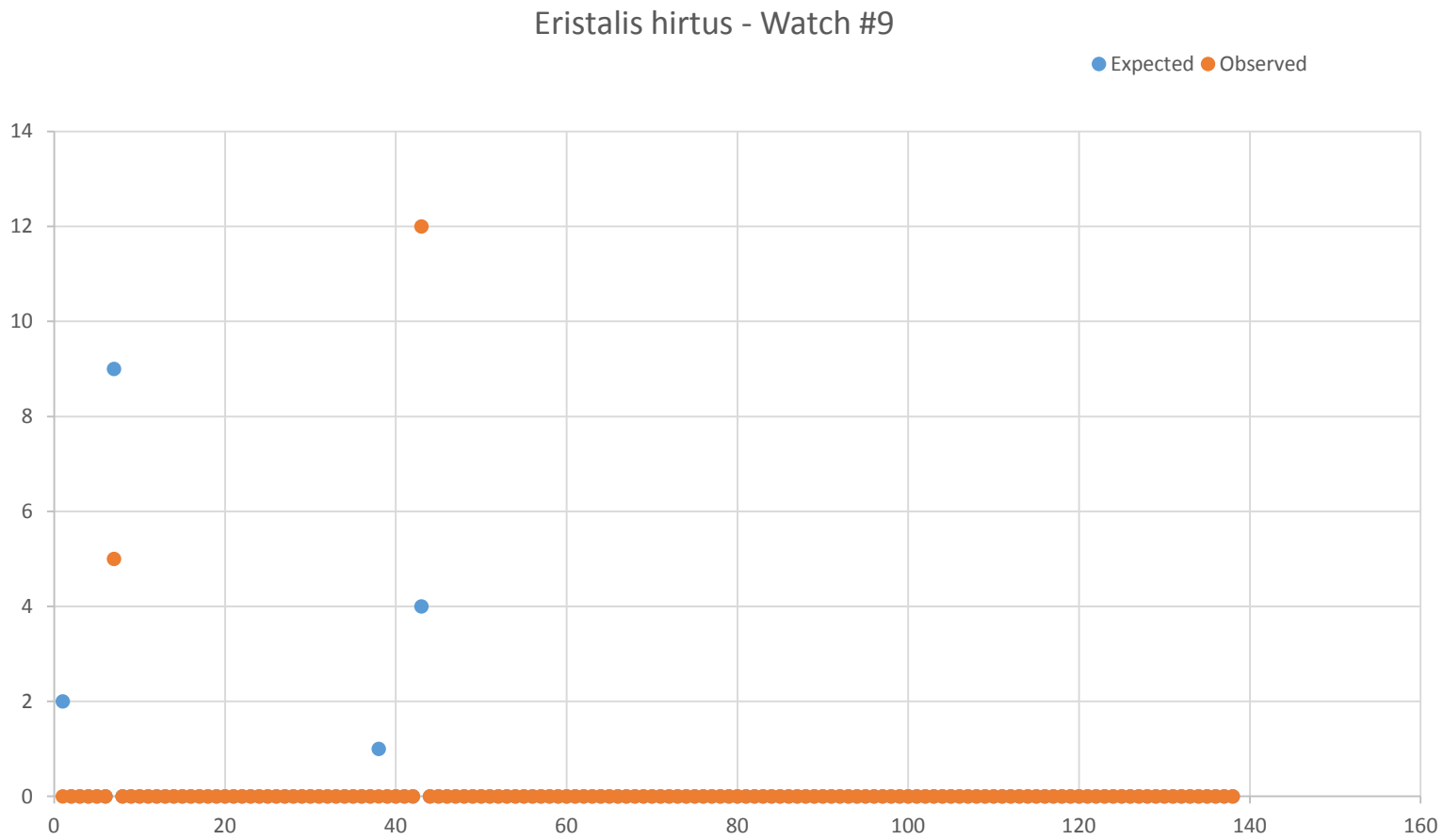
4. Compares optimized preferences list against observed interactions for all 3 years:

We reject the optimized preferences list for all insects.


Eristalis hirtus - Watch #1
Expected
Observed
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160


Eristalis hirtus - Watch #2
Expected
Observed
700
600
500
400
300
200
100
0
0
20
40
60
80
100
120
140
160


Eristalis hirtus - Watch #8
Expected
Observed
30
25
20
15
10
5
0
0
20
40
60
80
100
120
140
160


Eristalis hirtus - Watch #9
Expected
Observed
14
12
10
8
6
4
2
0
0
20
40
60
80
100
120
140
160

Test 5

Since both the uniform preferences list and the optimized preferences list were rejected by our earlier tests, we can compare them in one statistical test to determine which is more accurate. We use the likelihood ratio test.

Our resulting p-value for the test is 0*, so we reject the uniform preferences list, and conclude that our optimized preferences list is more accurate.

In Conclusion

Pollinators do not have flower selection strategies that rely solely on flower frequency.

Our optimized preferences list, though being rejected by the chi-squared test for goodness-of-fit, still predicts pollinator interactions better than the uniform preferences list.

Further Research

What factors influence preferences for flowers?

Do these preferences change over time?

How can we augment our model to more closely resemble what is actually occurring in the meadows?

Acknowledgements

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And to Eddie Helderop for moral support.