Flight Graphs

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Winter 2020

Cenzer Lab

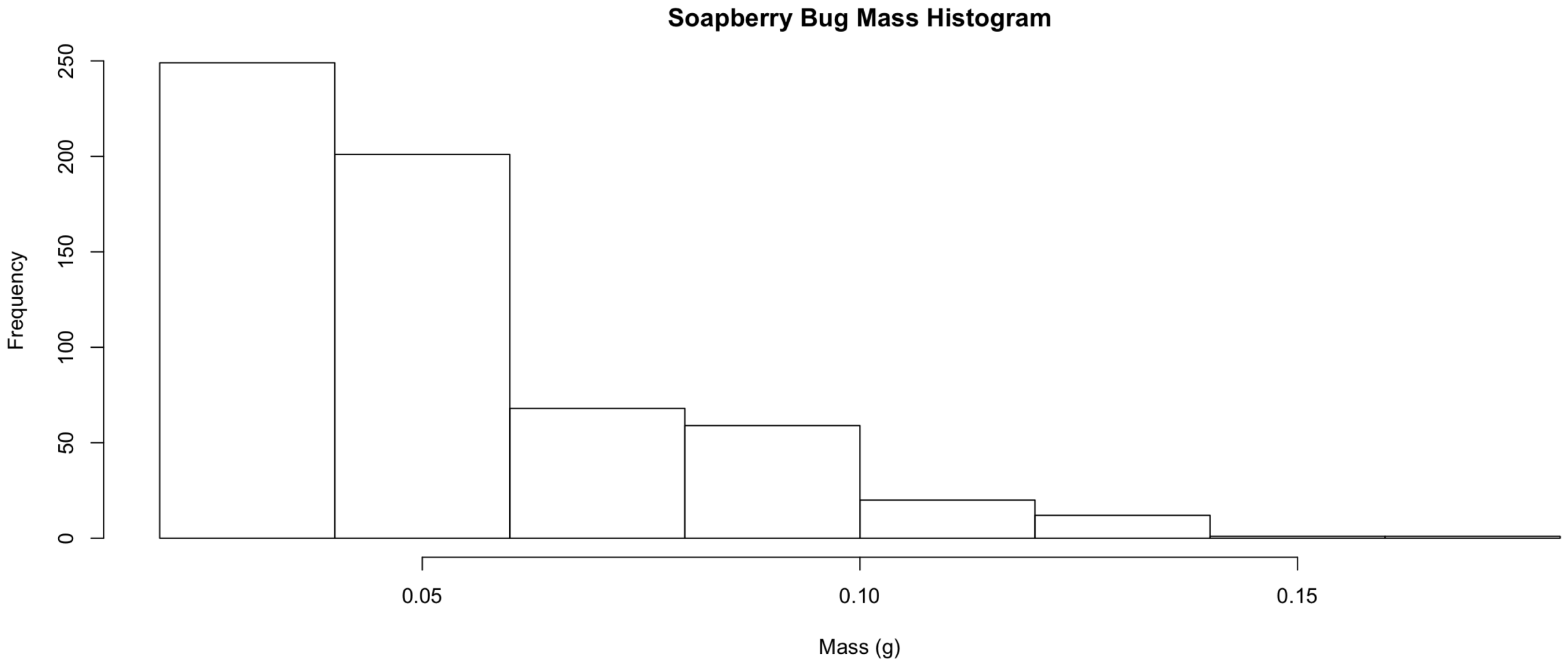
University of Chicago, E&E

Basic Numbers

Want to create nice tables of the regression best fit models and of general numbers like sample size, who flew or not, etc.

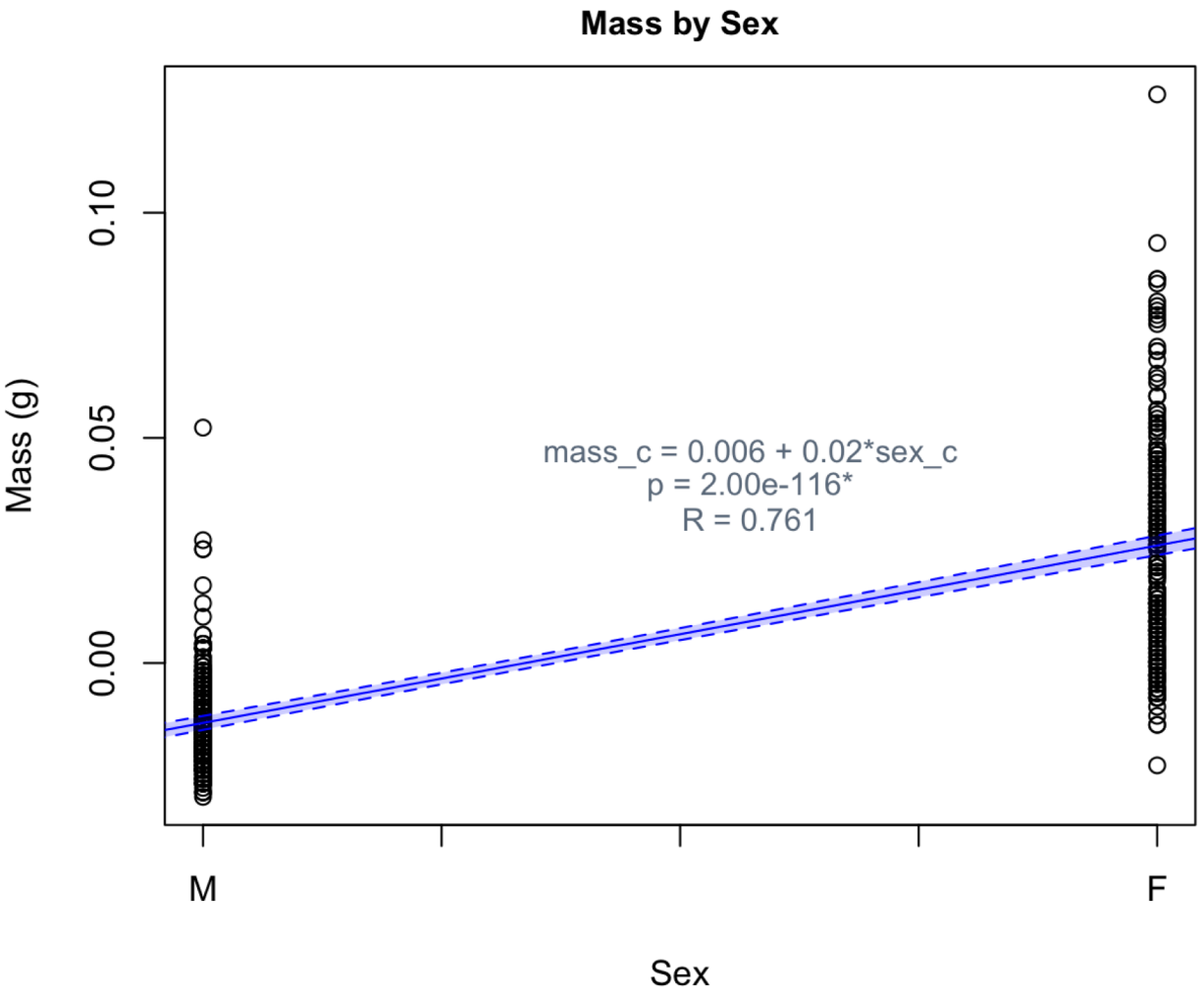
Mass Modeling

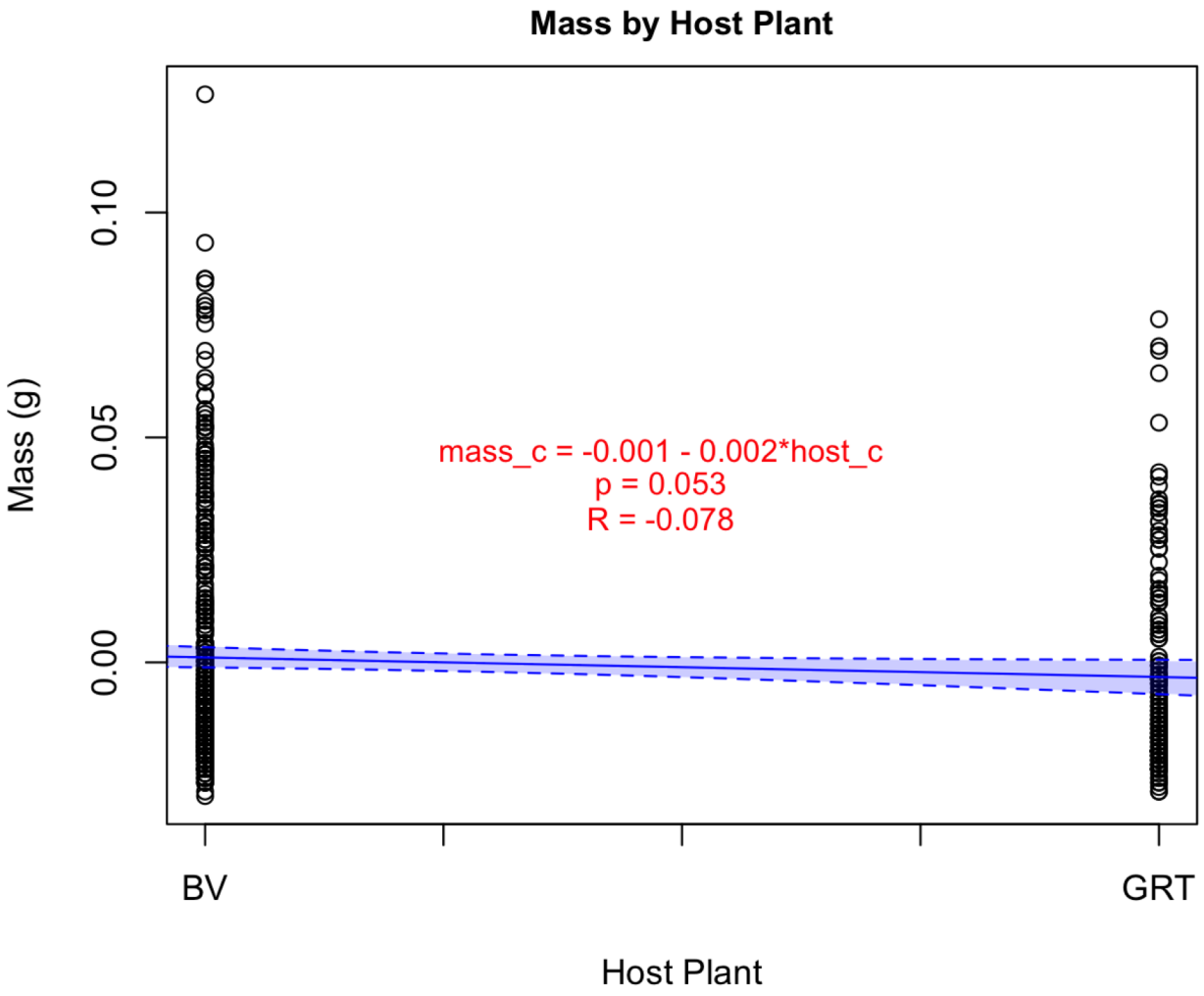
All Data


Soapberry Bug Mass Histogram
Frequency
0
50
100
150
200
250
0.05
0.10
0.15
Mass (g)

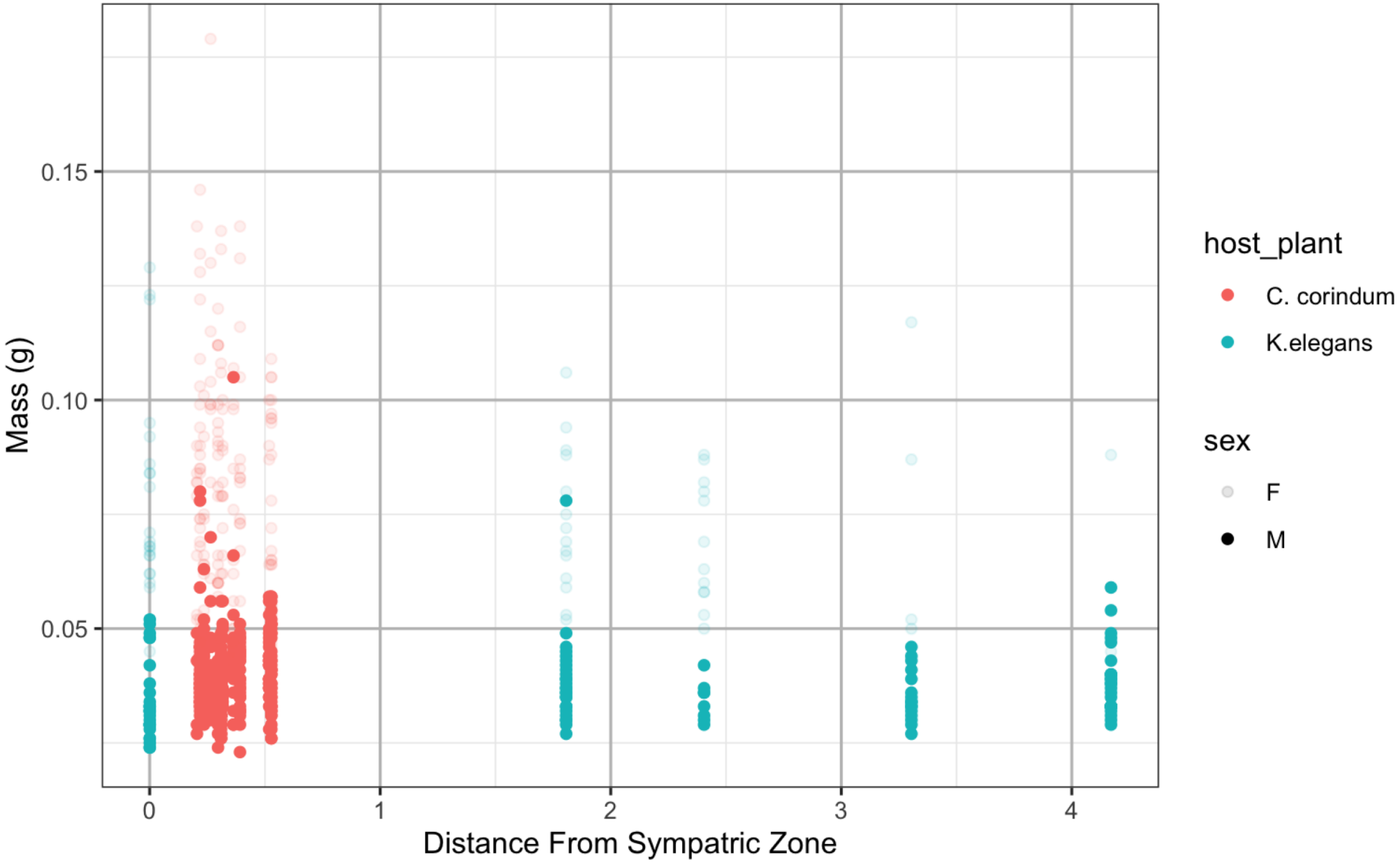
All Data

Best model



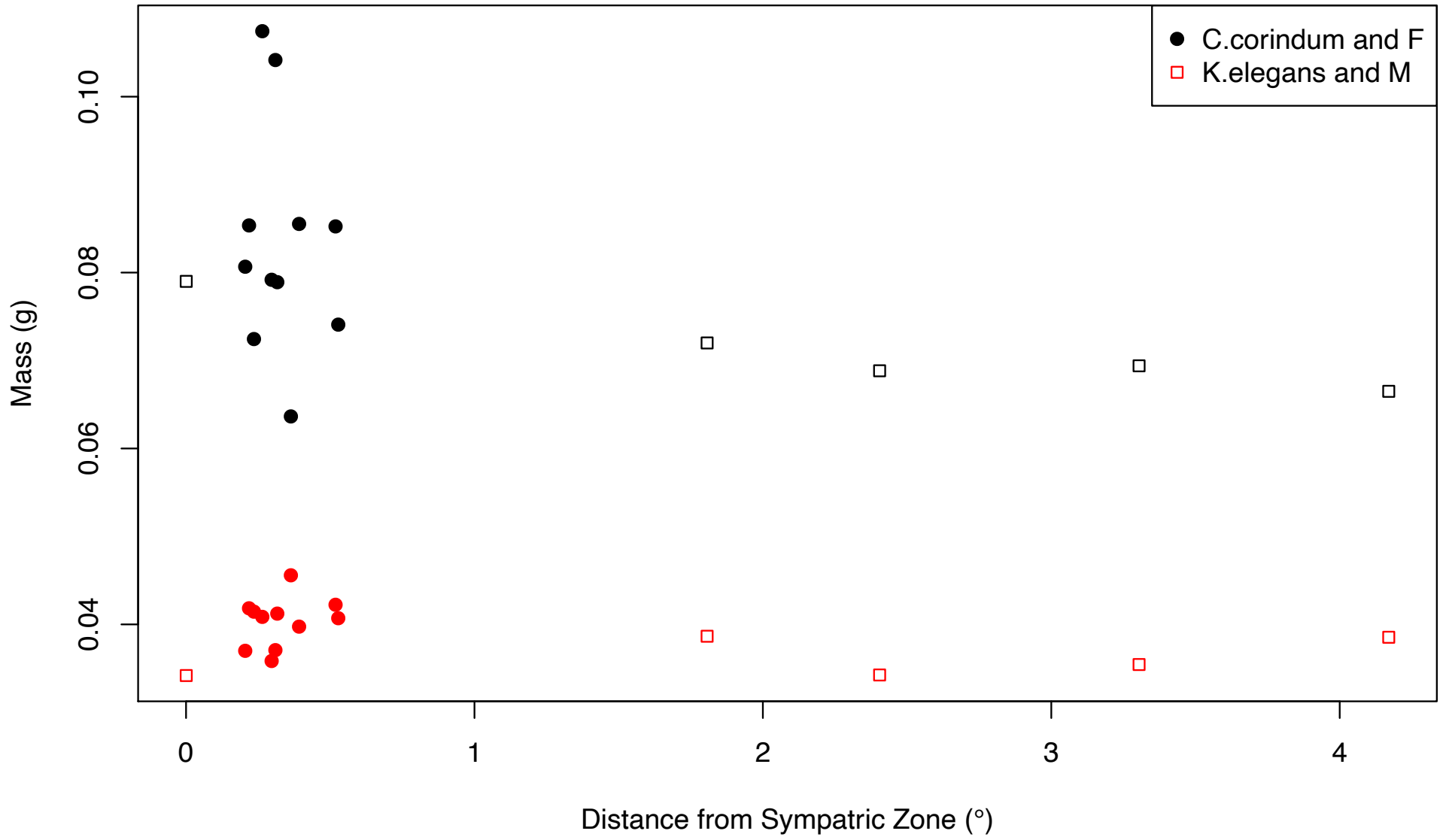


All Data


Mass (g)
0.15
0.10
0.05
0
1
2
3
4
Distance From Sympatric Zone
host_plant
C. corindum
K.elegans
sex
F
M

All Data

Observed Data



Morphology Modeling of Mass

All Data

Best models:

lmer mass_c ~ beak_c * wing_c + thorax_c * body_c + (1 | ID) + (1 | trial_type) data_tested

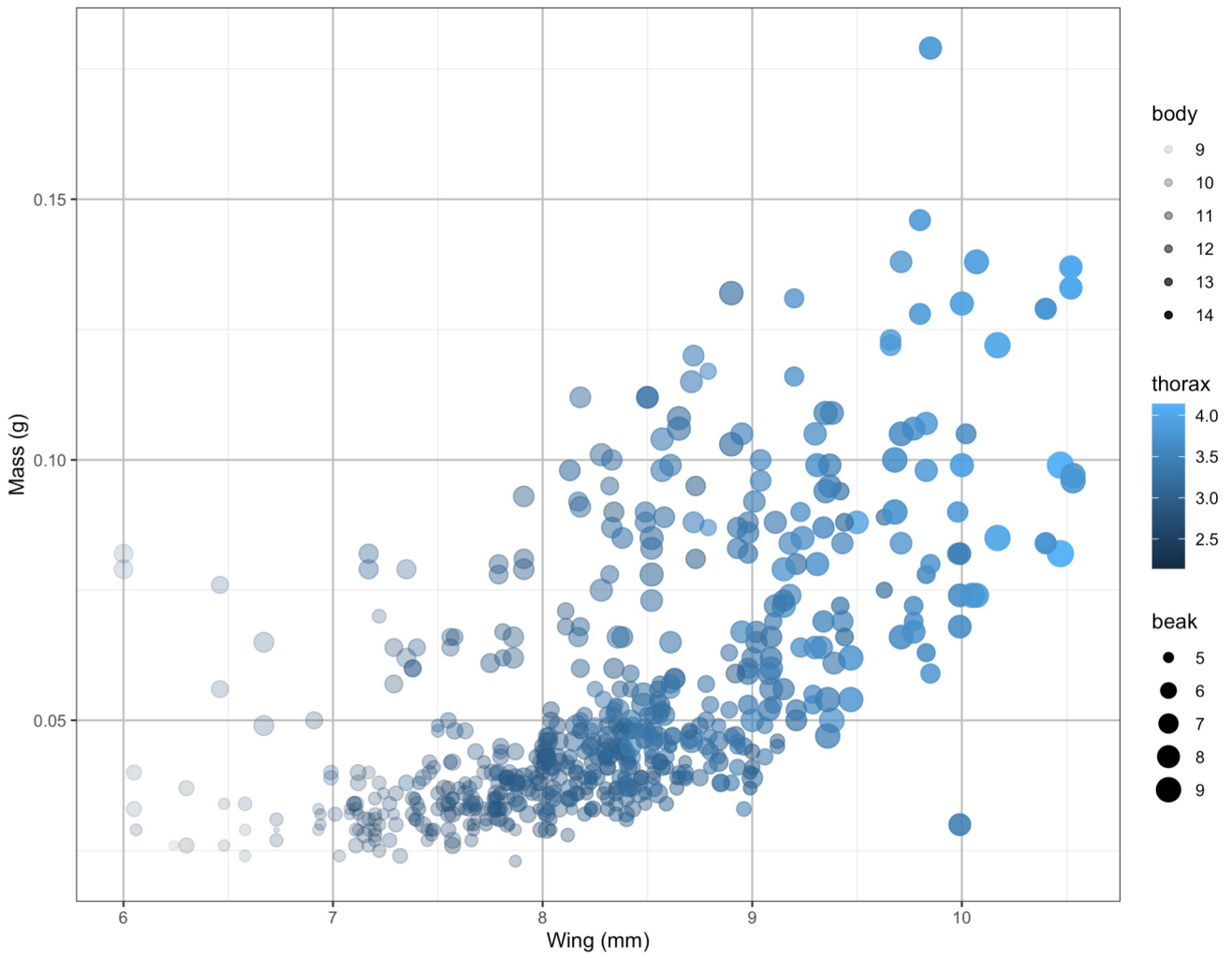
AIC: -3518.624

(Intercept)	coeff: -0.0027448	tval: -1.525037
beak_c	coeff: 0.0121958	tval: 7.929734
wing_c	coeff: -0.0195708	tval: -4.753276
thorax_c	coeff: 0.0123469	tval: 1.975261
body_c	coeff: 0.0191039	tval: 4.614781
beak_c:wing_c	coeff: -0.0083005	tval: -5.924242
thorax_c:body_c	coeff: 0.02078	tval: 7.217669

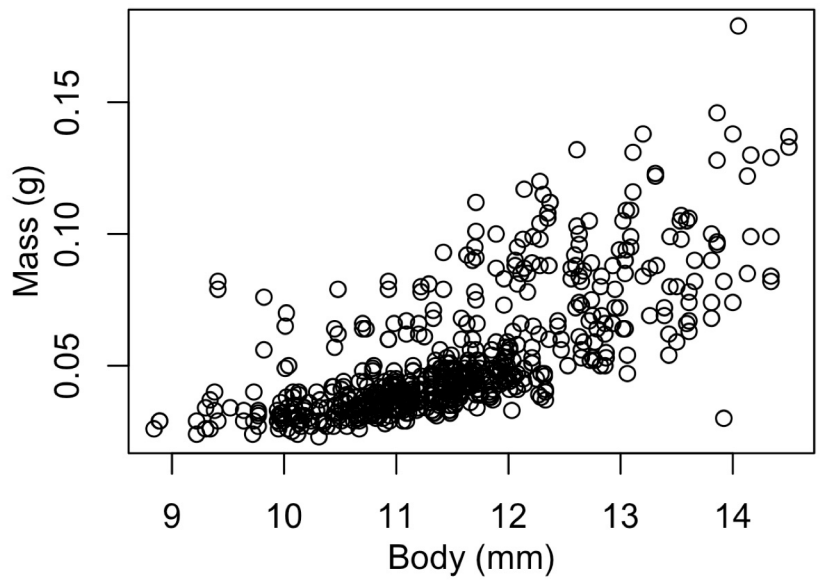
lmer mass_c ~ beak_c * wing2body_c + thorax_c + (1 | ID) + (1 | trial_type) data_tested

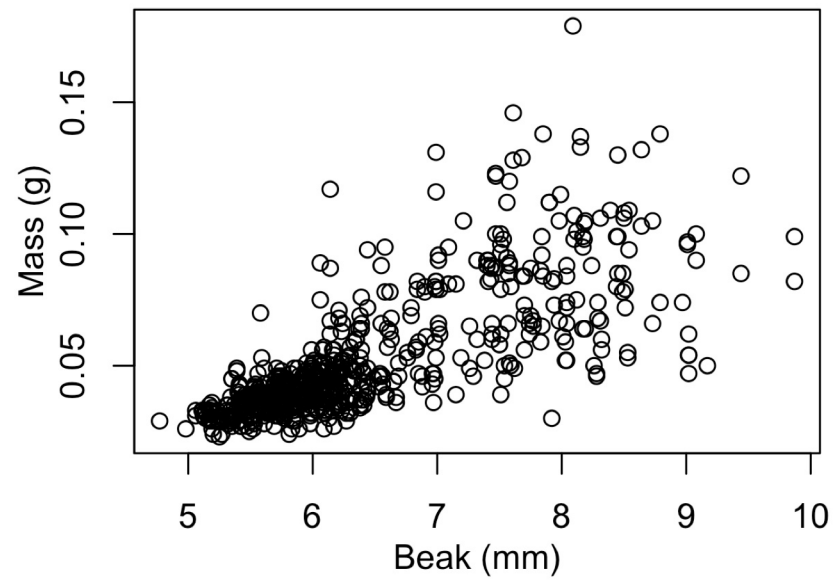
AIC: -3506.214

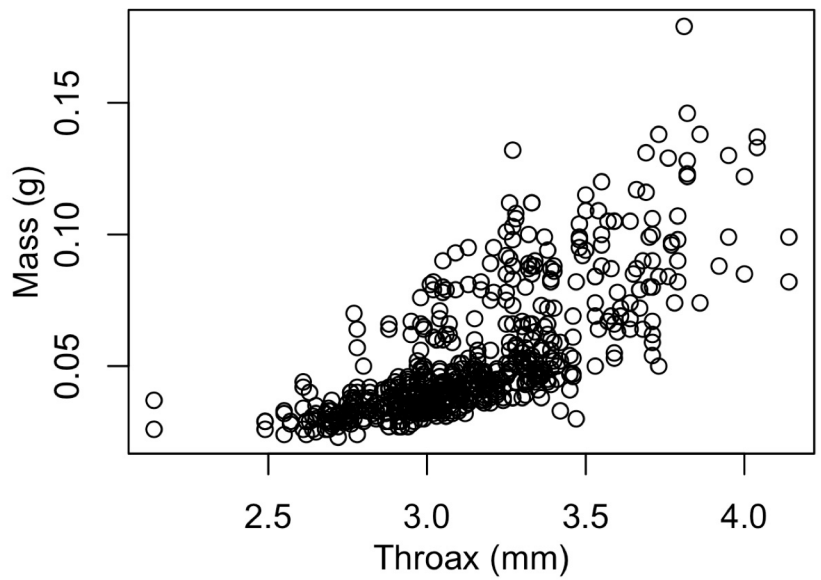
(Intercept)	coeff: -0.0019251	tval: -1.121806
beak_c	coeff: 0.0087008	tval: 7.317061
wing2body_c	coeff: -0.2271249	tval: -5.228125
thorax_c	coeff: 0.0365509	tval: 9.454628
beak_c:wing2body_c	coeff: -0.1704865	tval: -3.786103

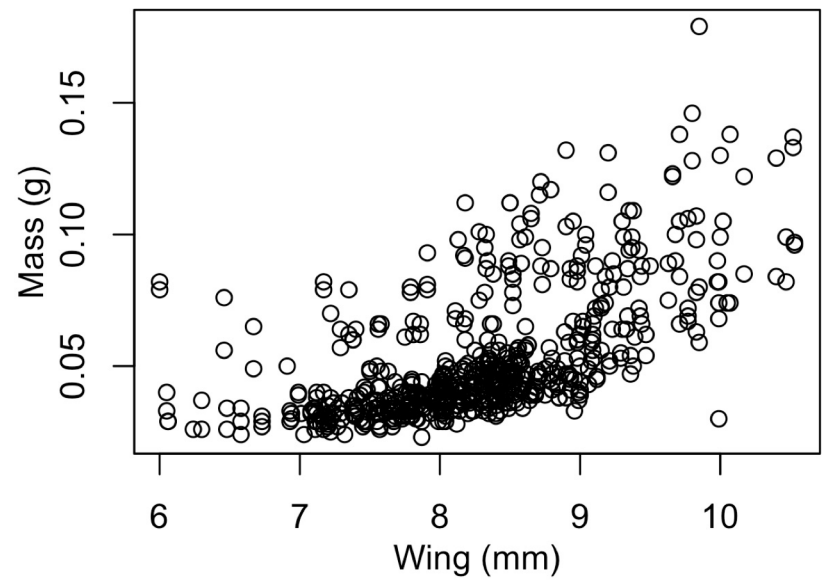


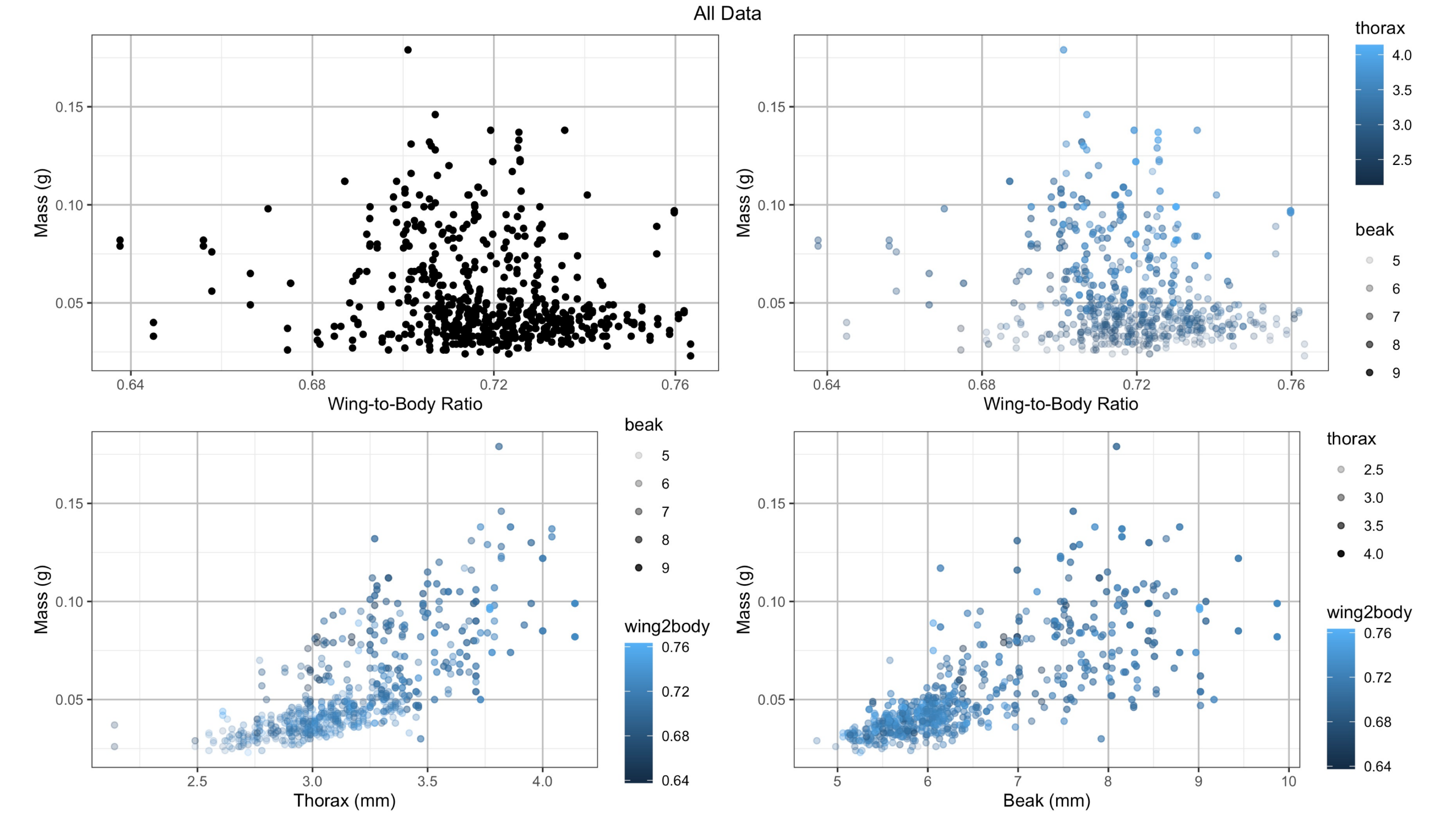
All Data


Mass (g)
0.05
0.10
0.15
9
10
11
12
13
14
Body (mm)


Mass (g)
0.05
0.10
0.15
5
6
7
8
9
10
Beak (mm)

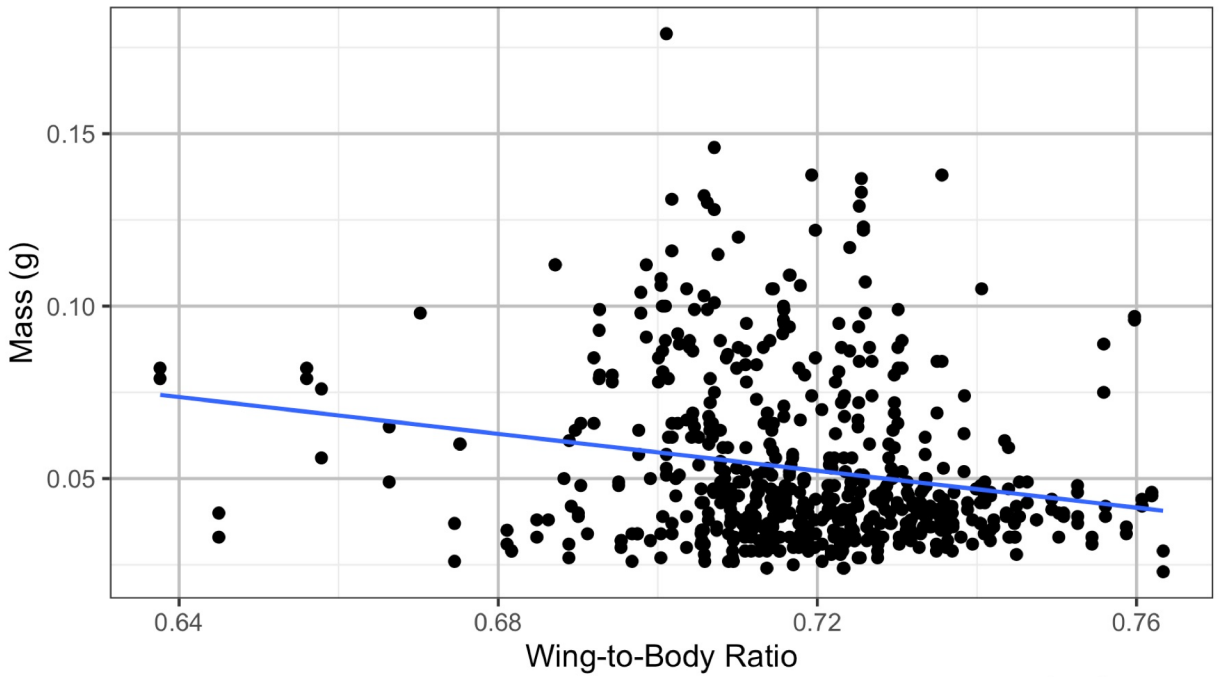

Mass (g)
0.05
0.10
0.15
2.5
3.0
3.5
4.0
Throax (mm)

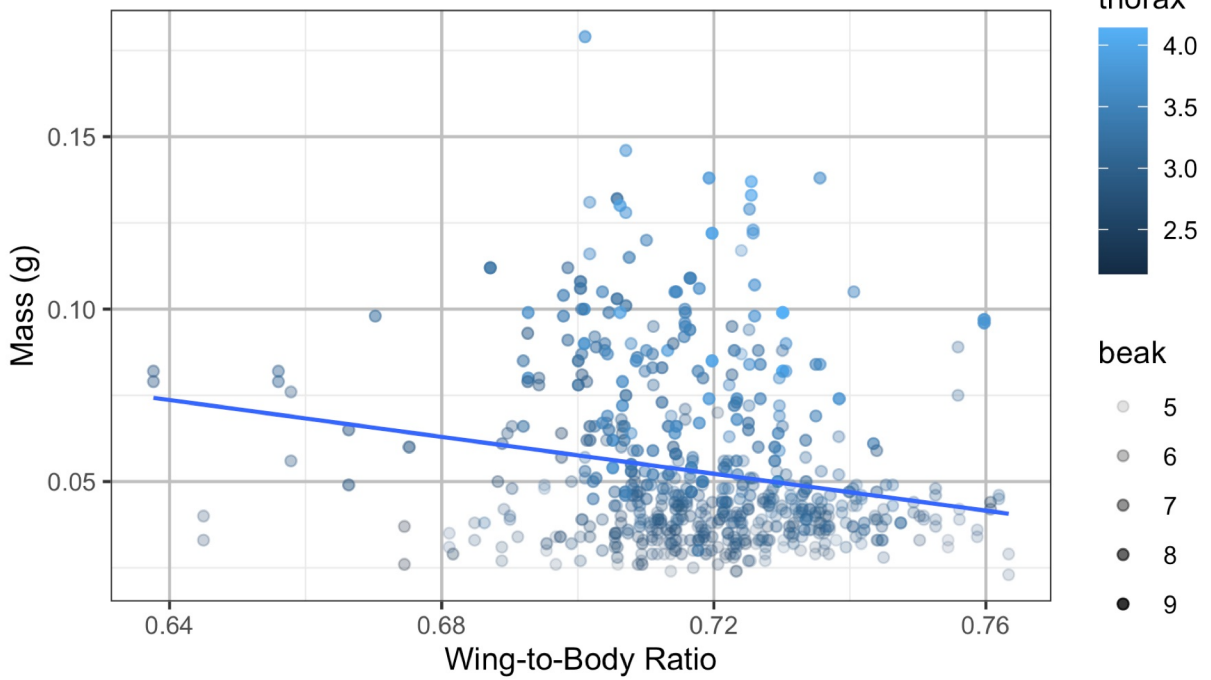

Mass (g)
0.05
0.10
0.15
6
7
8
9
10
Wing (mm)

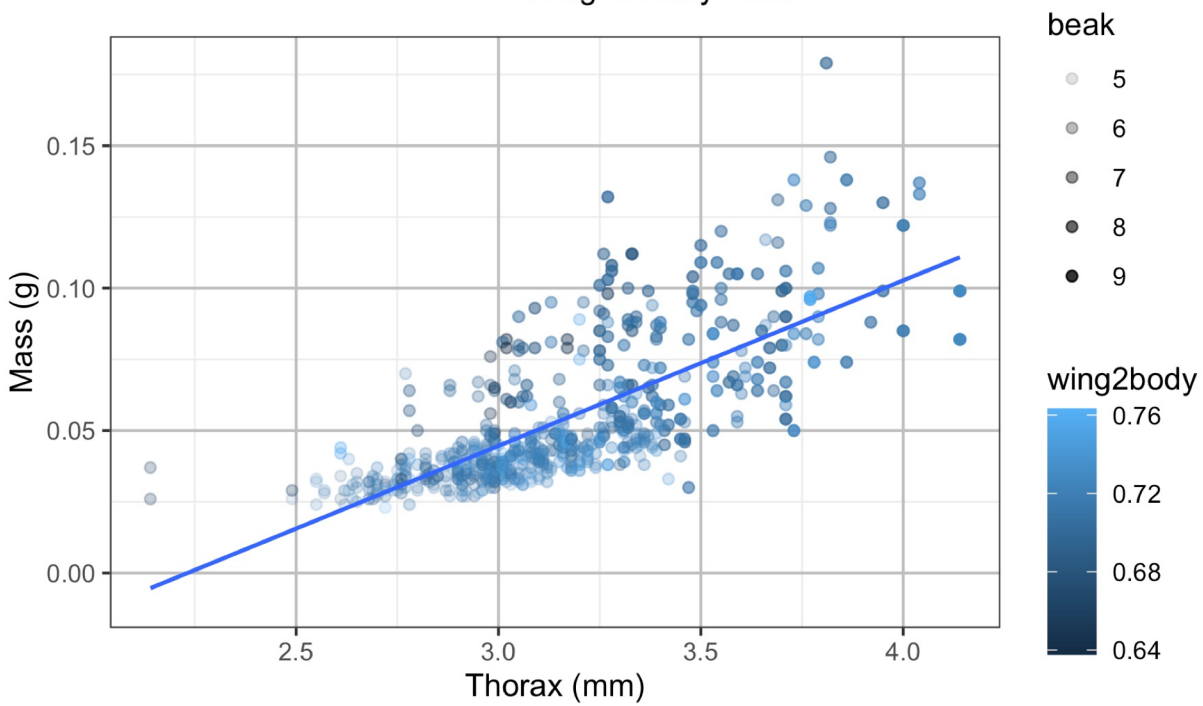

All Data
Mass (g)
0.15
0.10
0.05
0.64
0.68
0.72
0.76
Wing-to-Body Ratio
thorax
4.0
3.5
3.0
2.5
beak
5
6
7
8
9
Thorax (mm)
2.5
3.0
3.5
4.0
wing2body
0.76
0.72
0.68
0.64
Beak (mm)
5
6
7
8
9
10

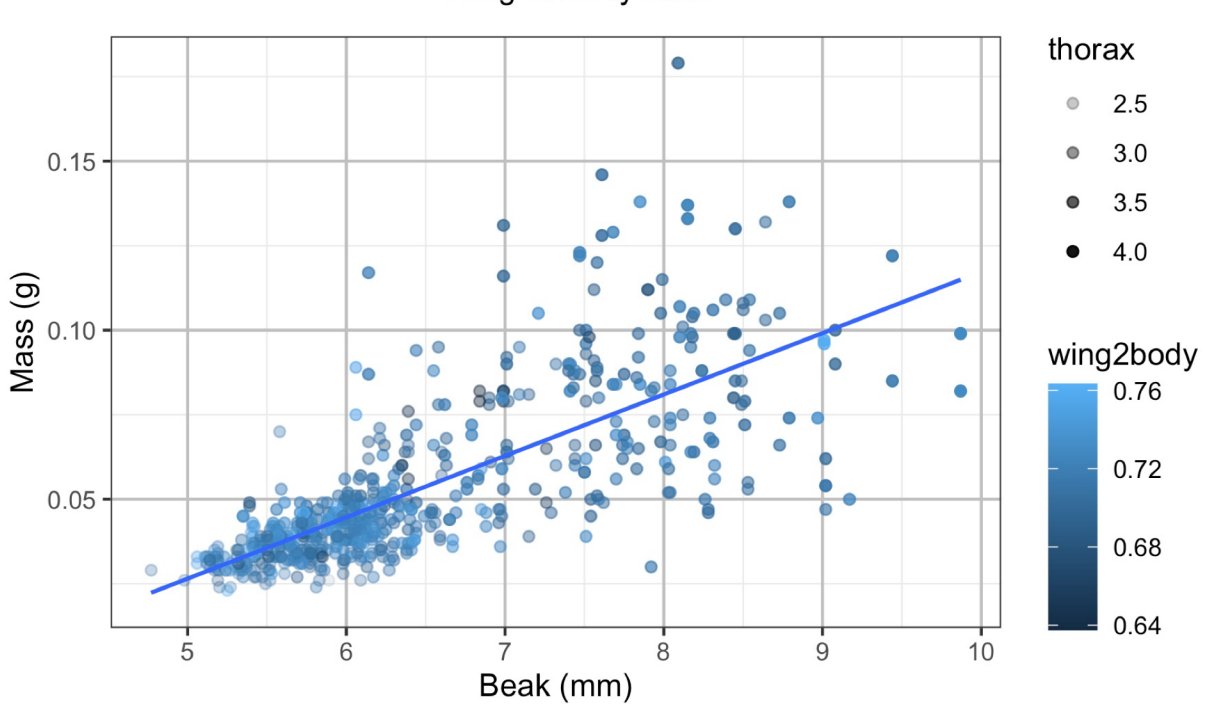
**Worth exploring these nonlinear relationships w/ polynomial regressions

All Data

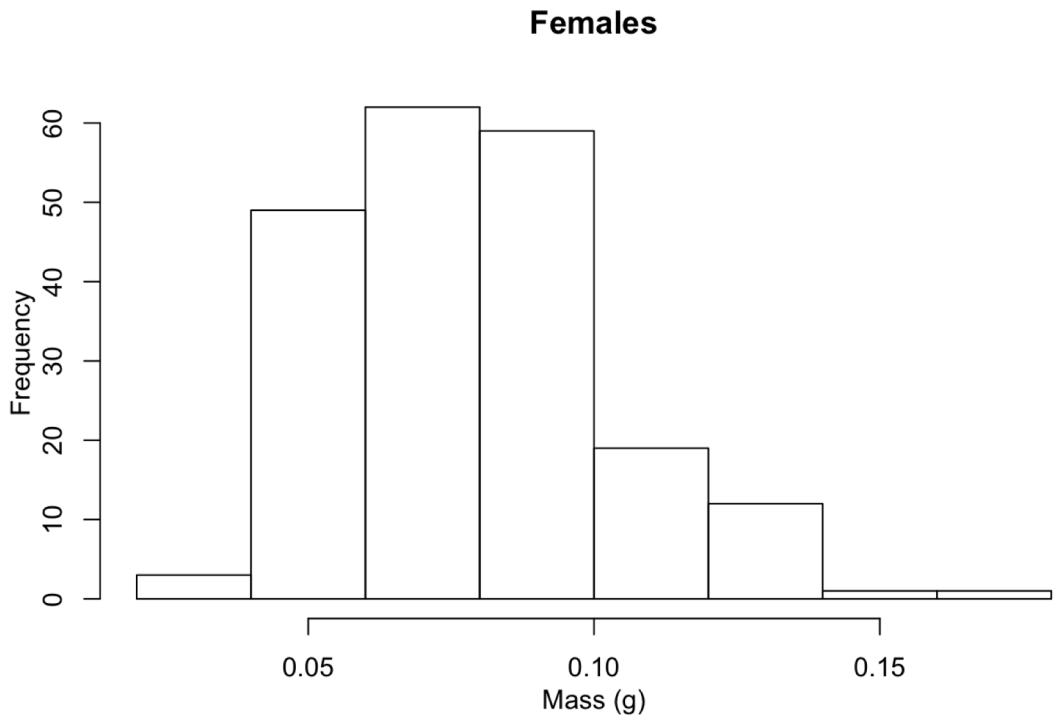


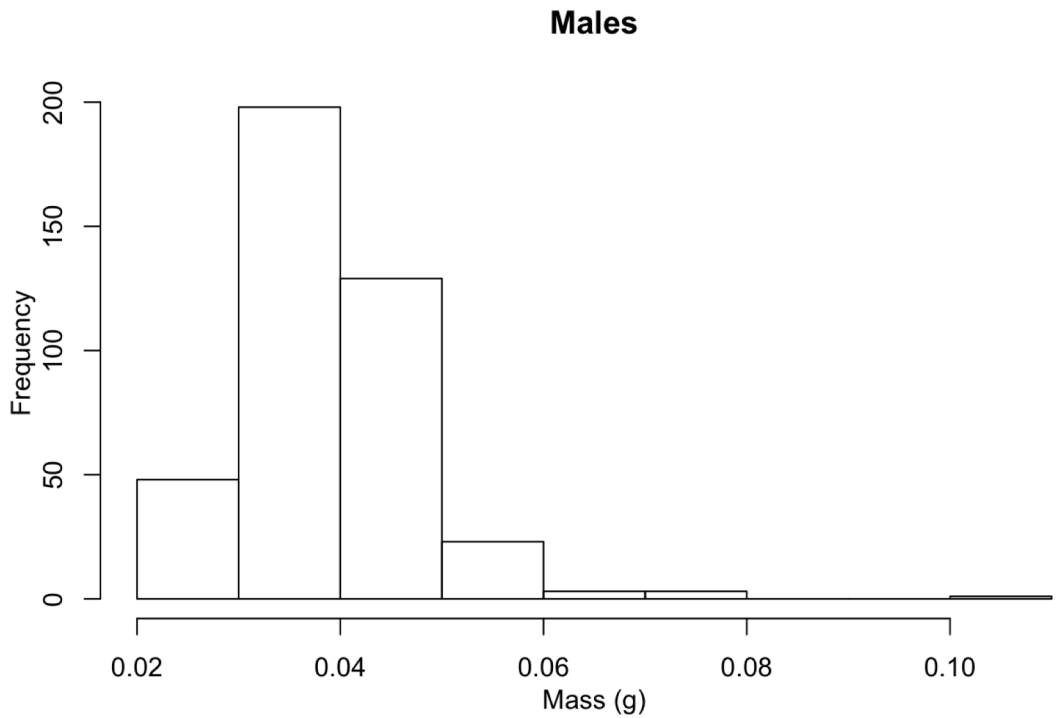




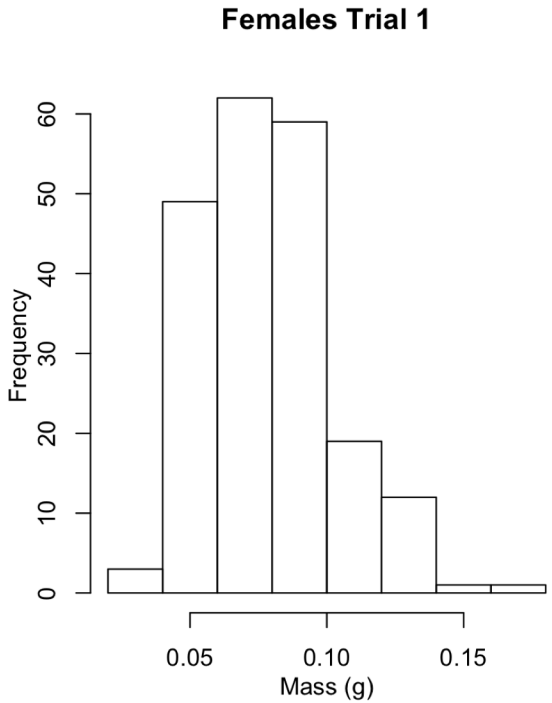


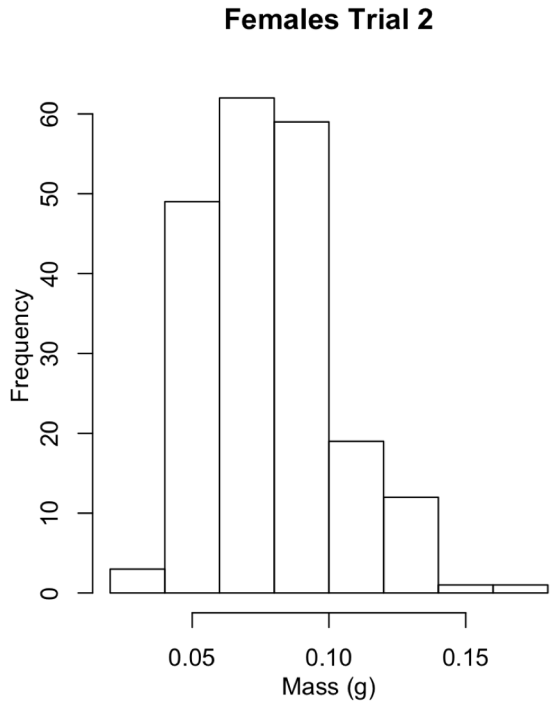
Separating by Sex

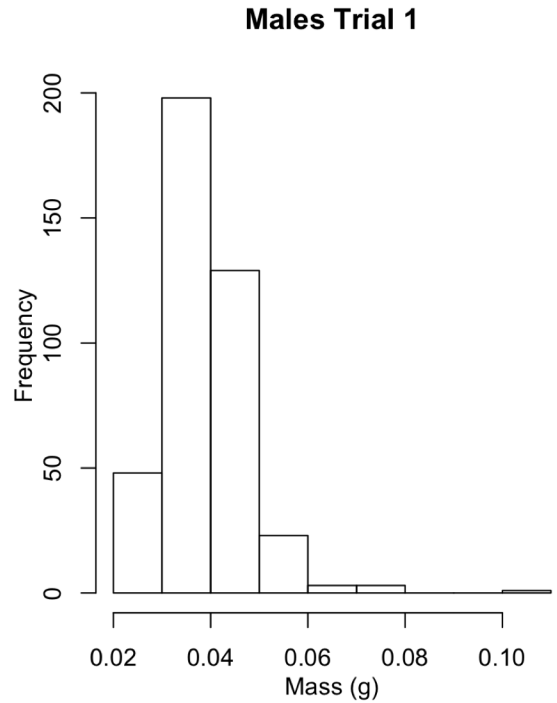


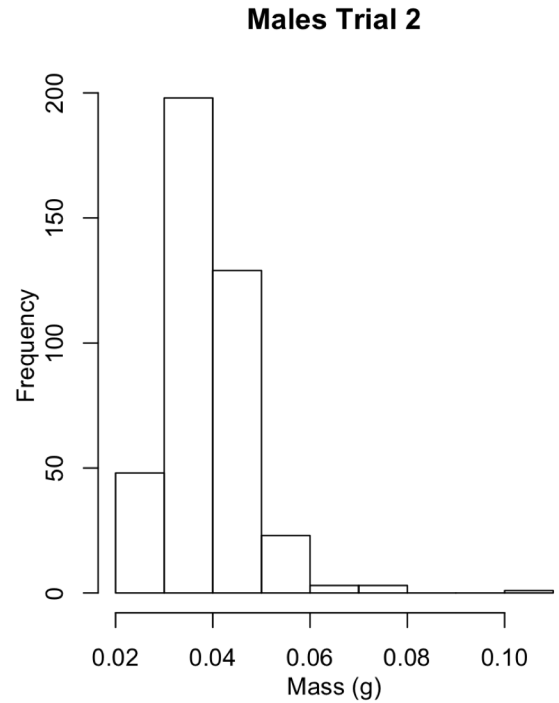


Separating by Sex and Trial







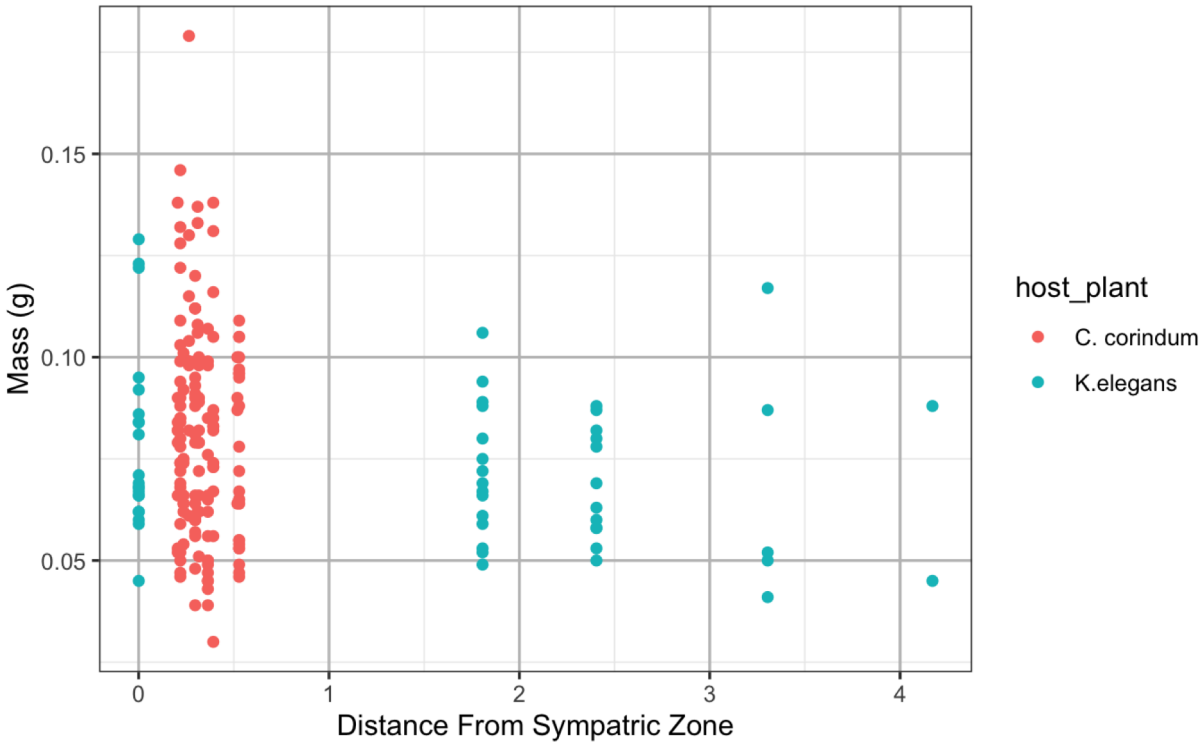


After modeling mass ~ sym_dist*host_plant between the sexes found these two models as the top models:

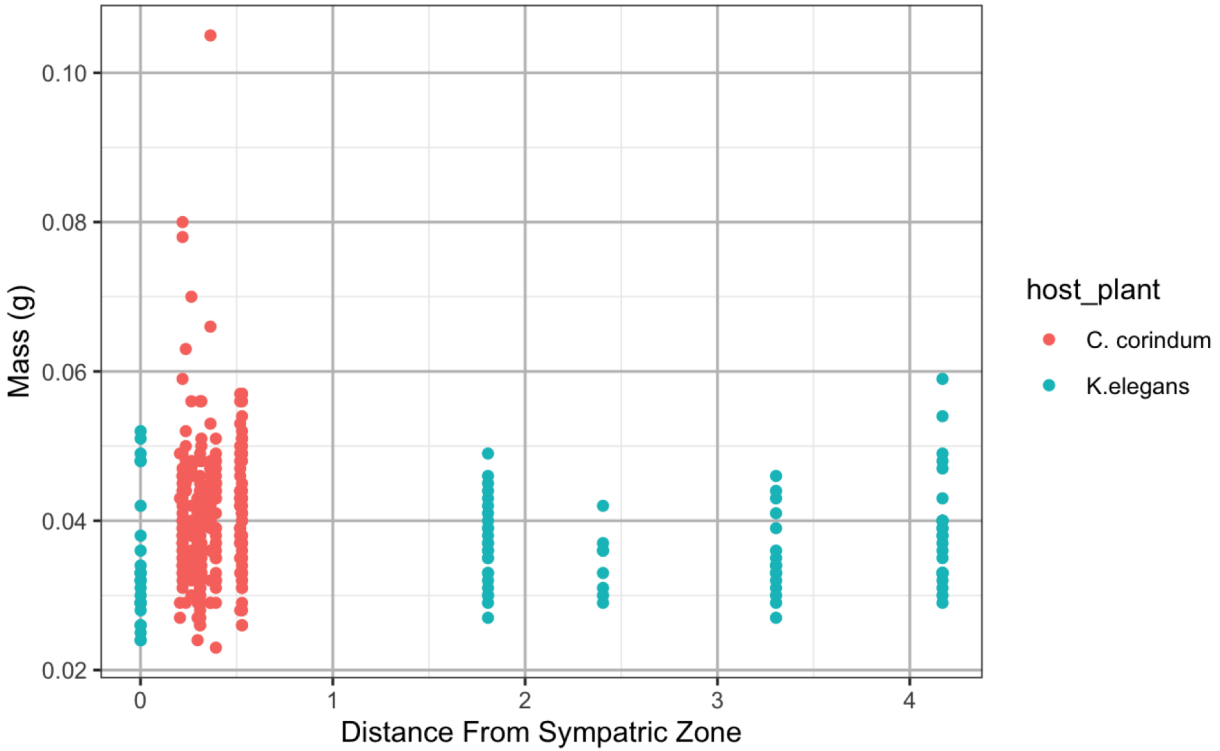
m0 <- R ~ (1 | ID)

m10 <- R ~ (1 | ID) + (1 | trial_type)

Female Data

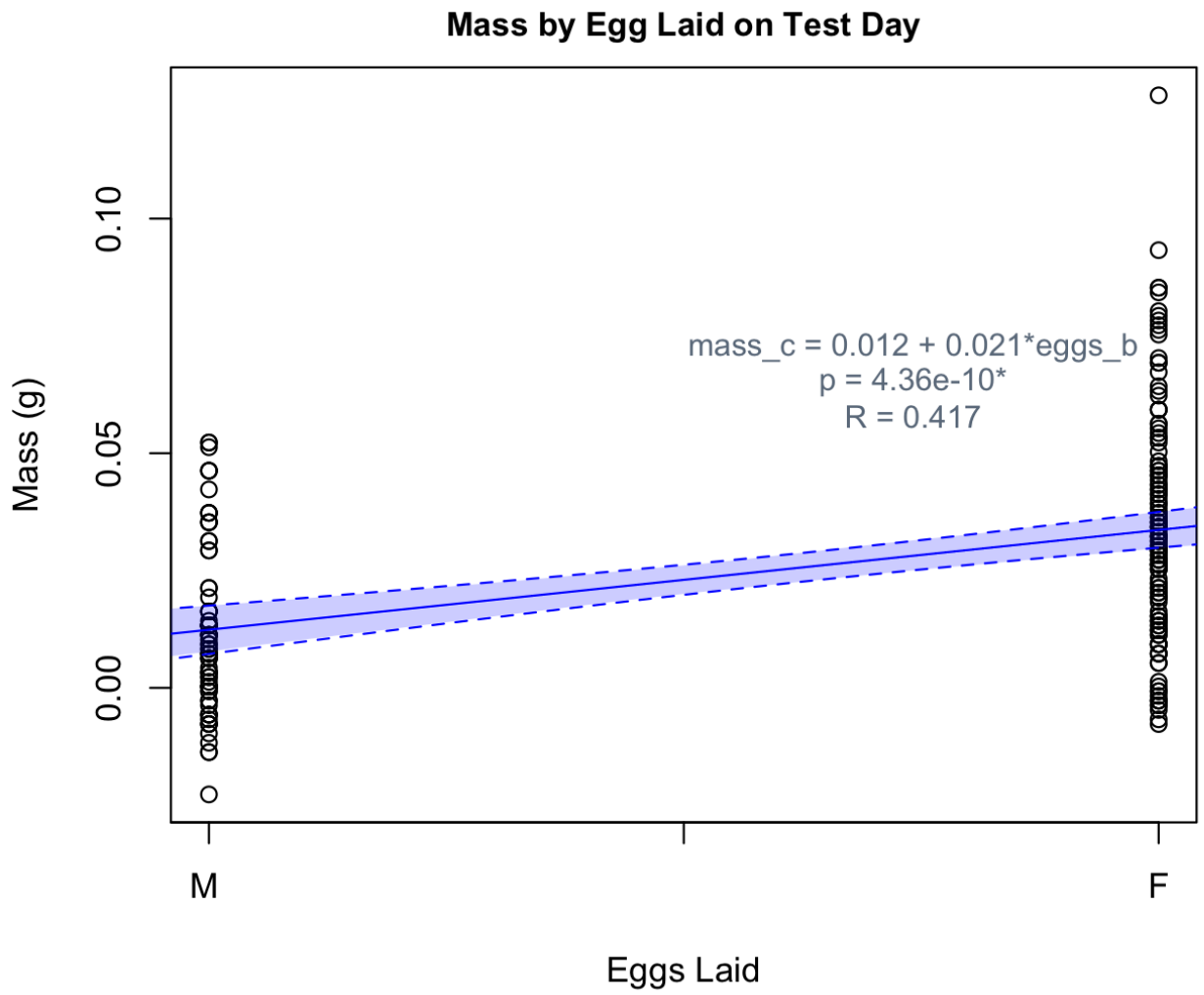


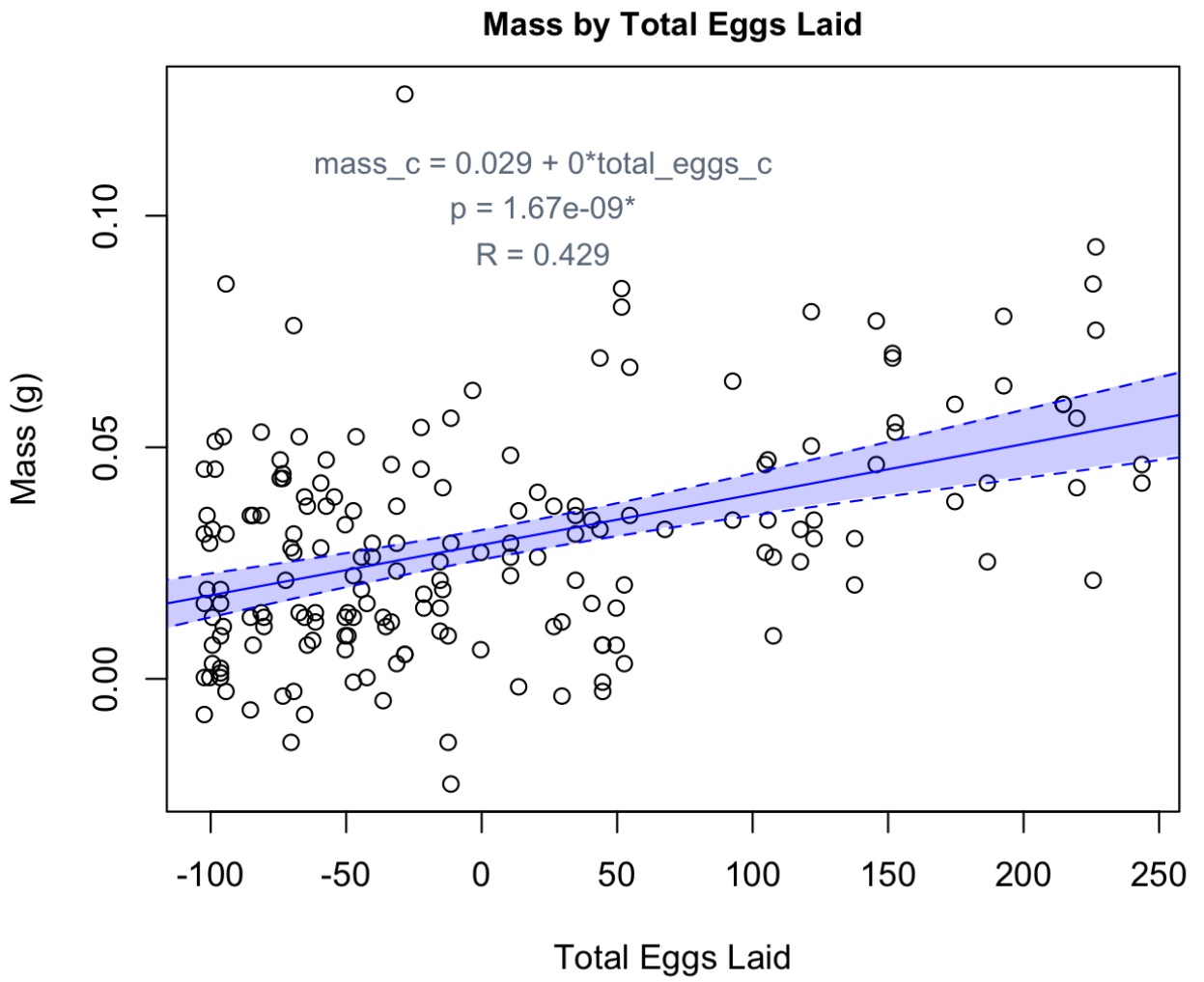
Male Data



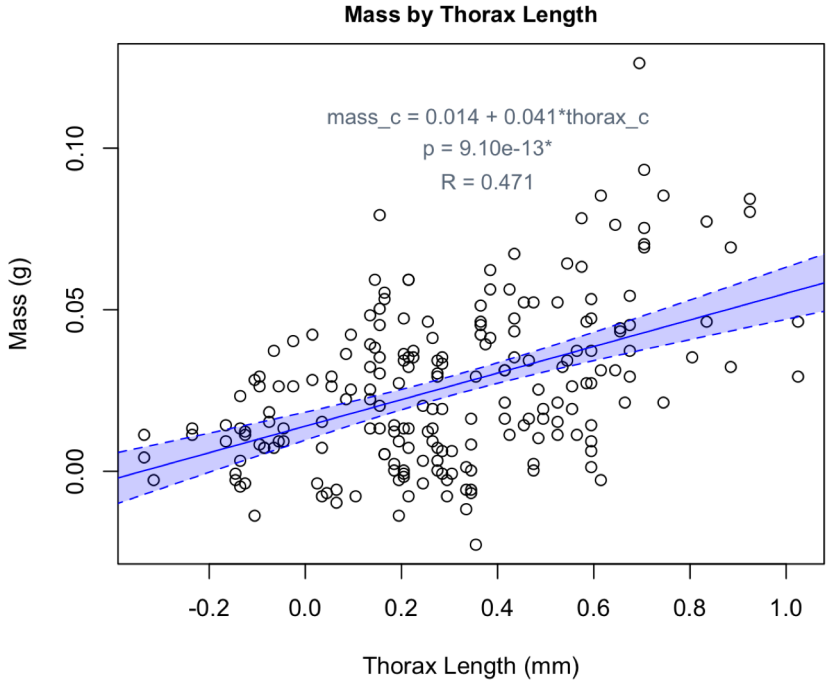
Female Data

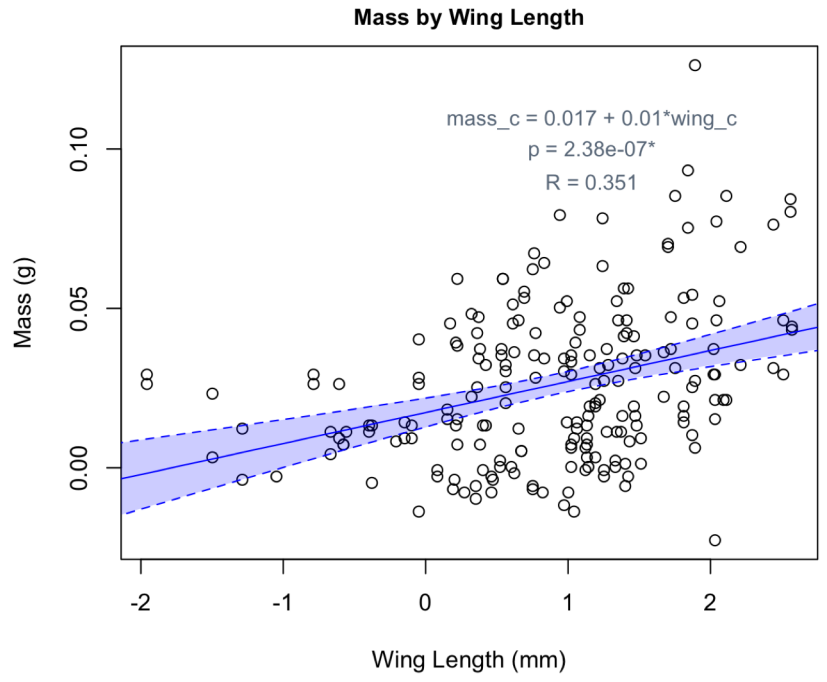
Best model

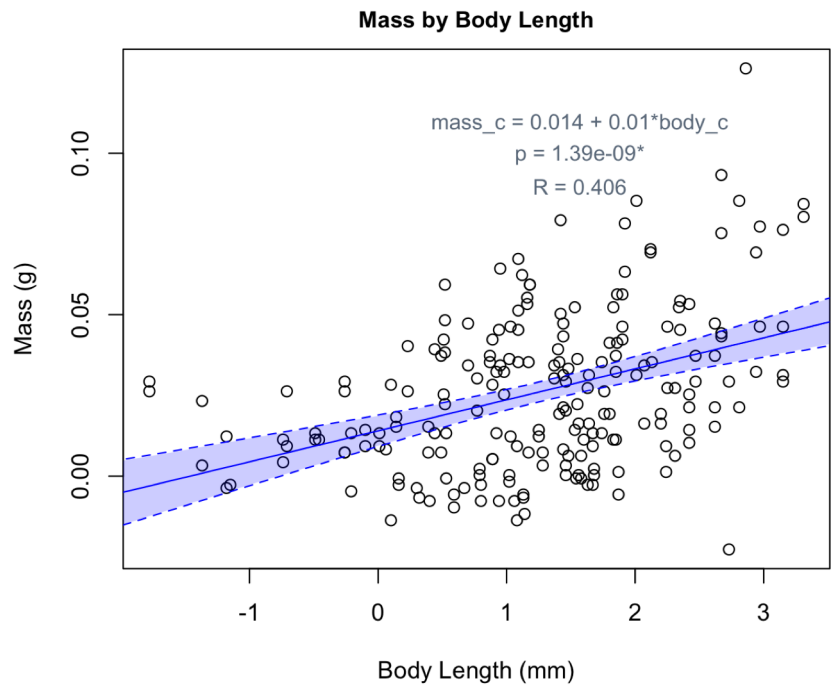


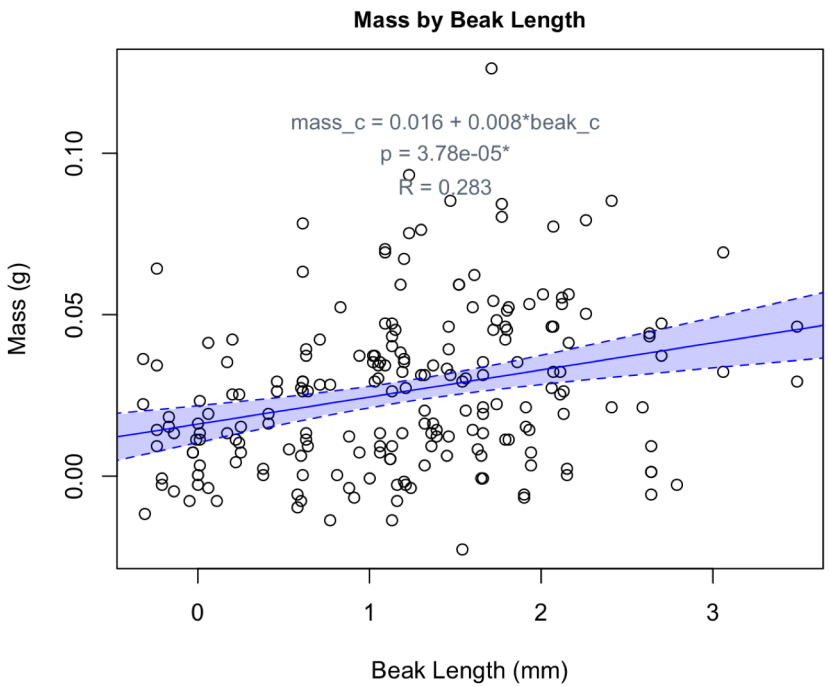


Best model









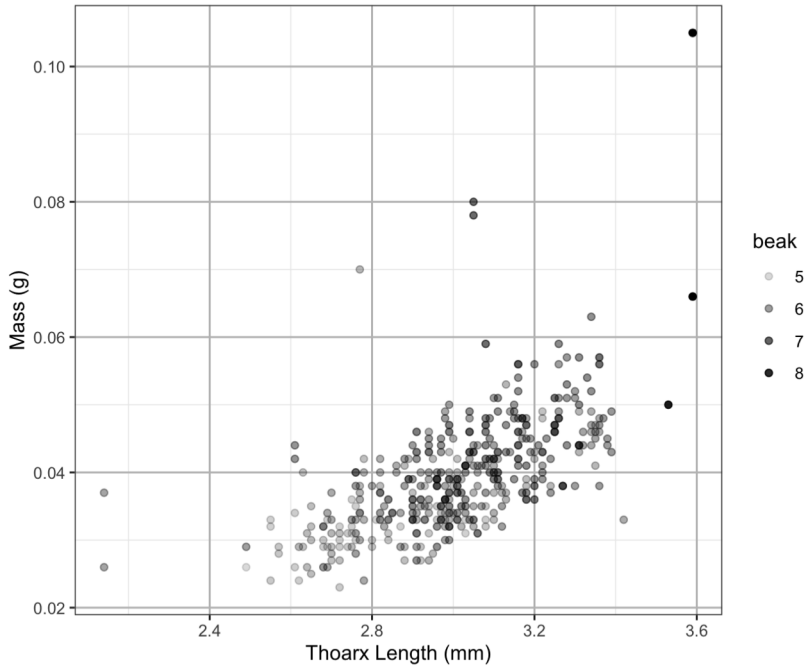
Female Data

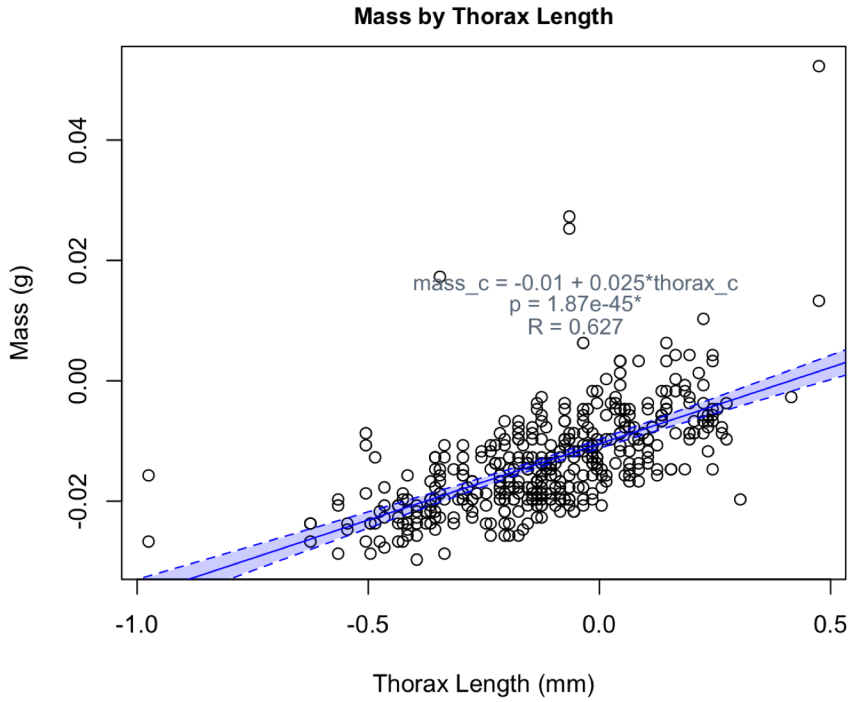
**Worth exploring these nonlinear relationships w/ polynomial regressions

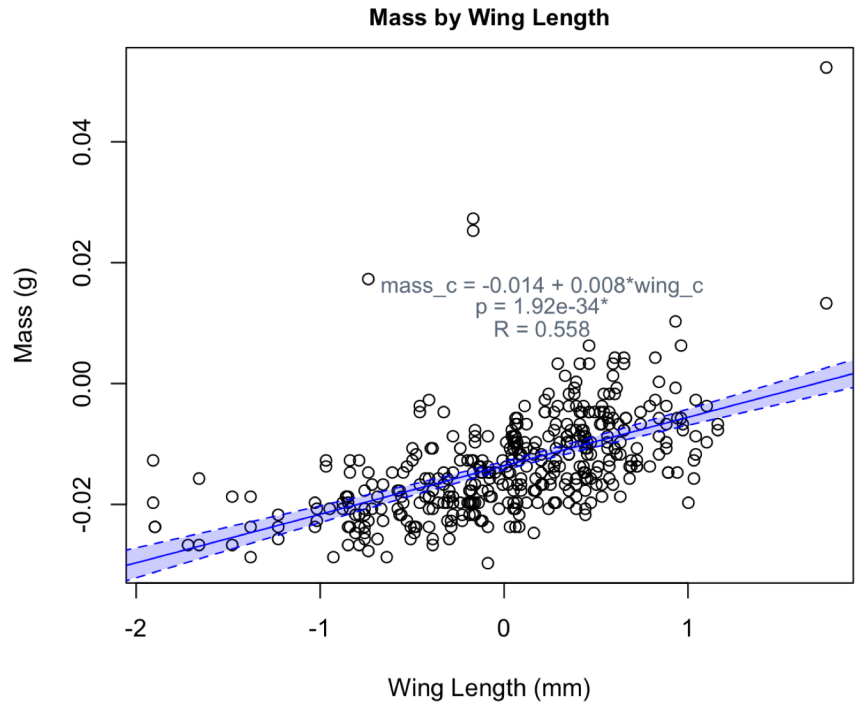
Male Data

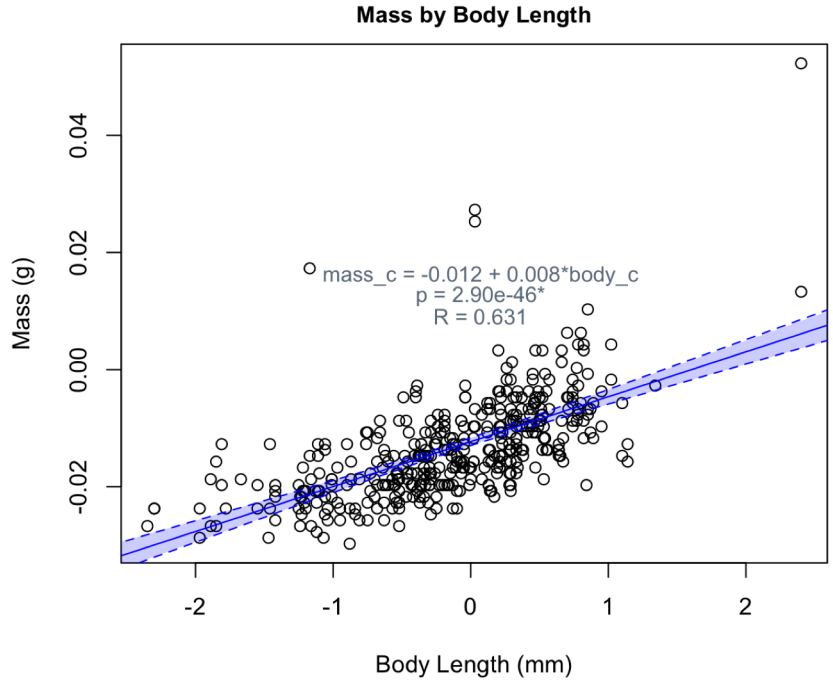
**Worth exploring these nonlinear relationships w/ polynomial regressions

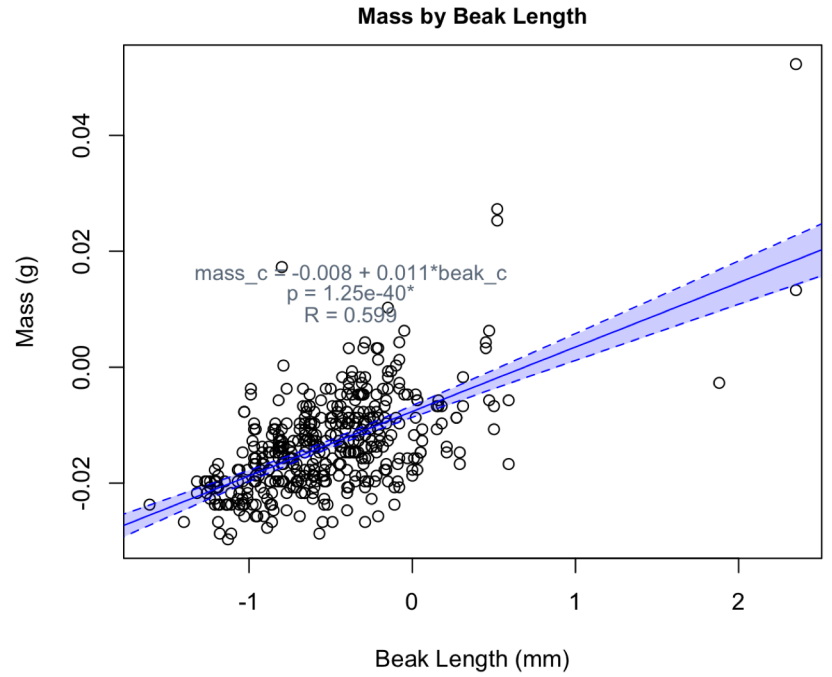
Best model: mass_c ~ beak_c + thorax_c + (1 | ID)



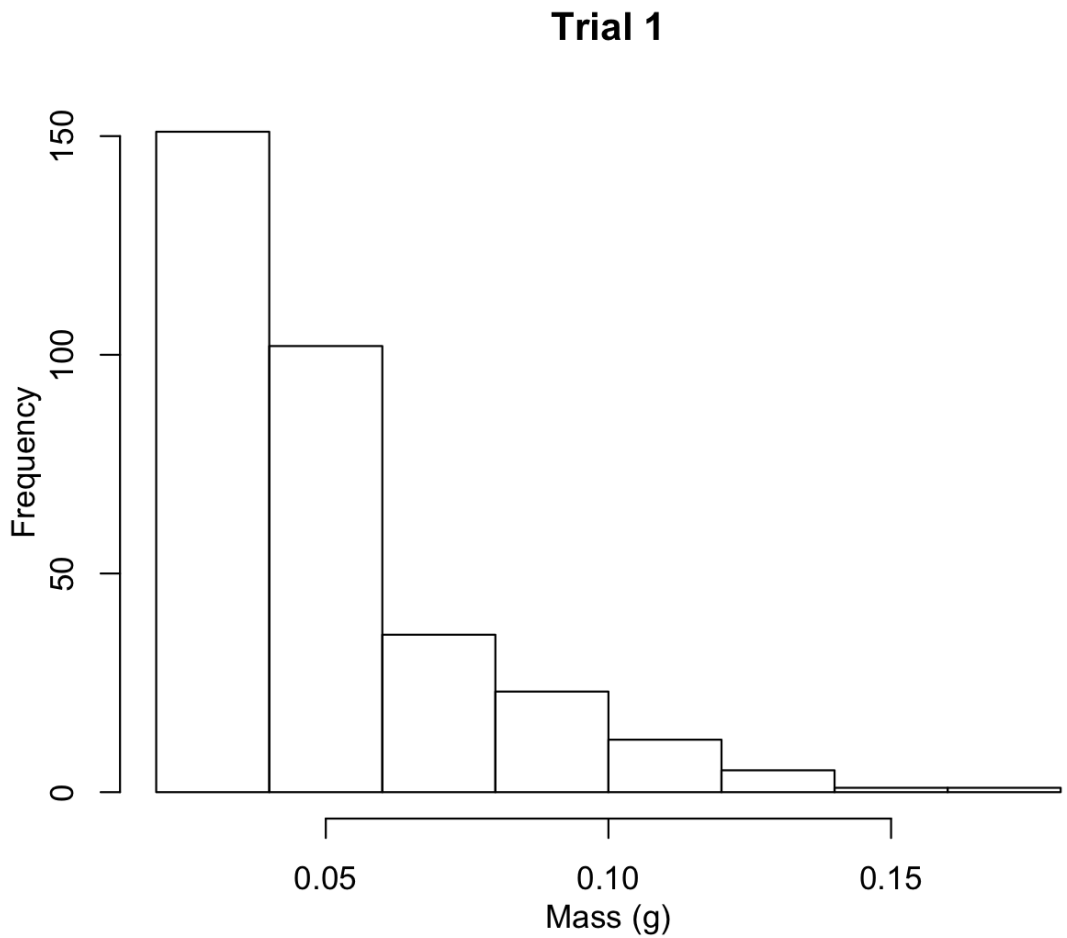


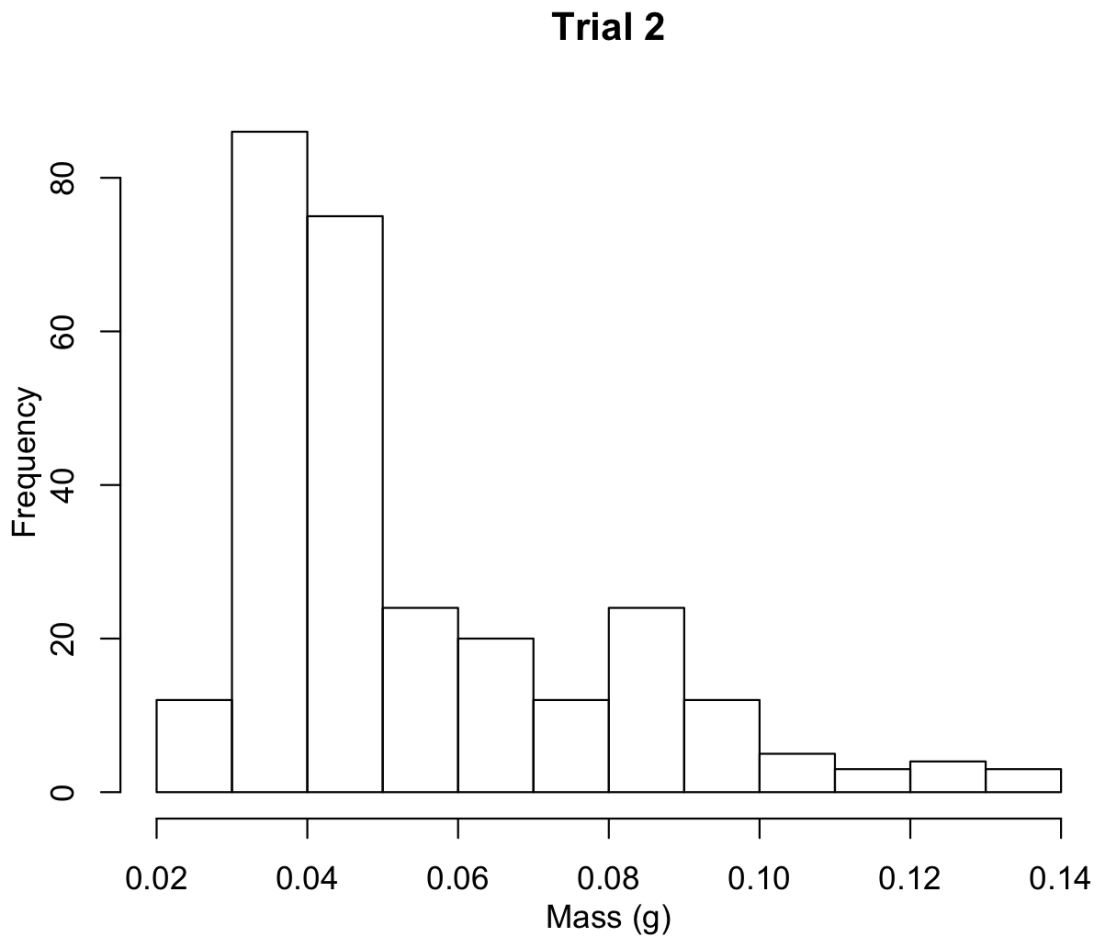




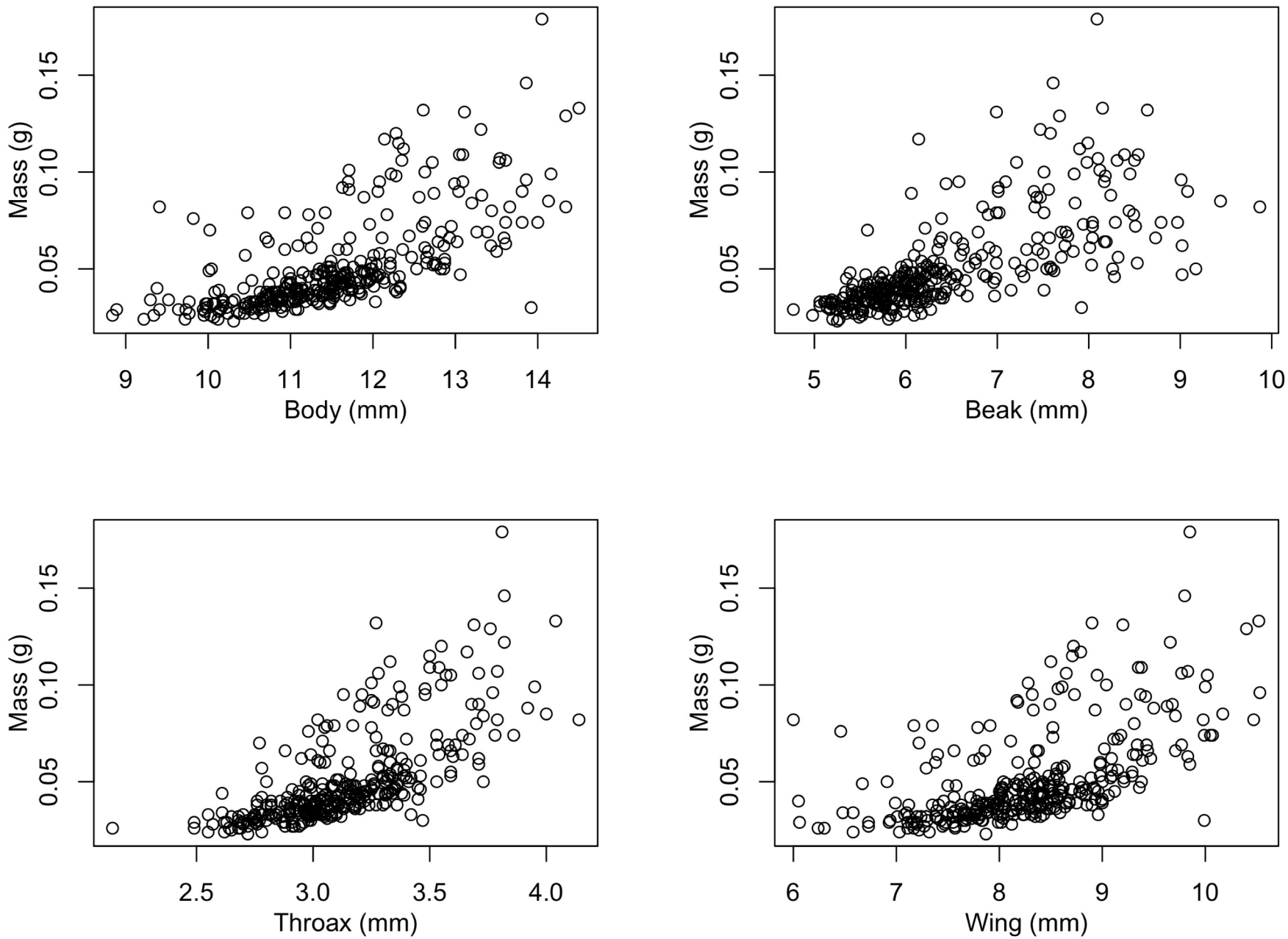


Separating by Trial

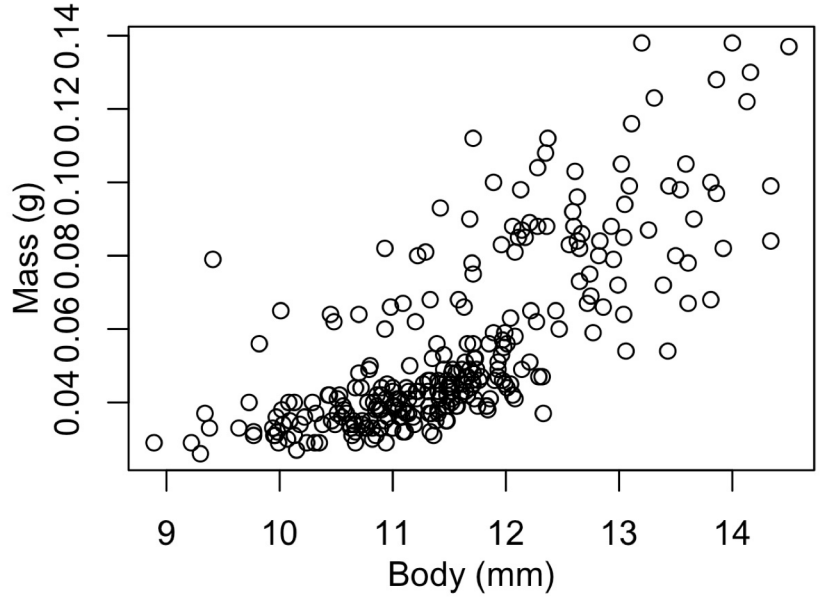


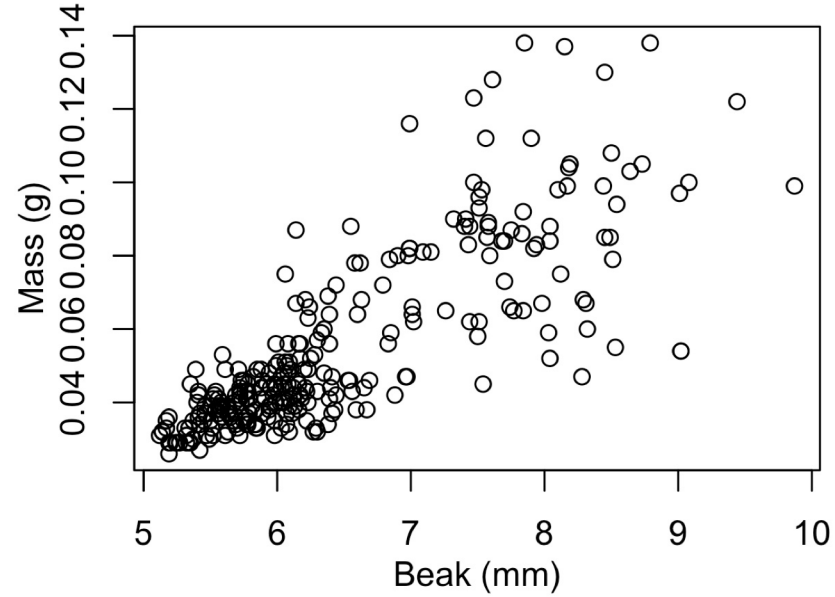


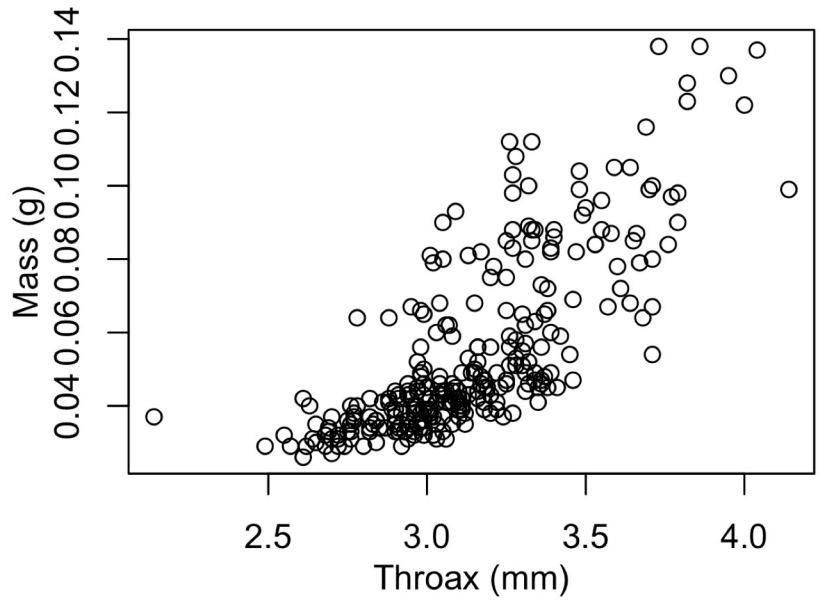
Trial 1

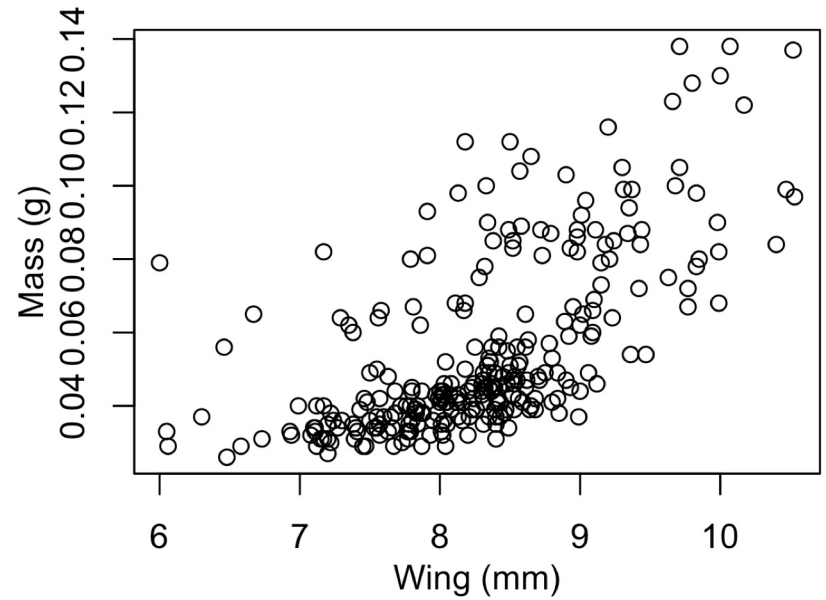

Mass (g)
0.05
0.10
0.15
9
10
11
12
13
14
Body (mm)
Mass (g)
0.05
0.10
0.15
5
6
7
8
9
10
Beak (mm)
Mass (g)
0.05
0.10
0.15
2.5
3.0
3.5
4.0
Throax (mm)
Mass (g)
0.05
0.10
0.15
6
7
8
9
10
Wing (mm)

Trial 2

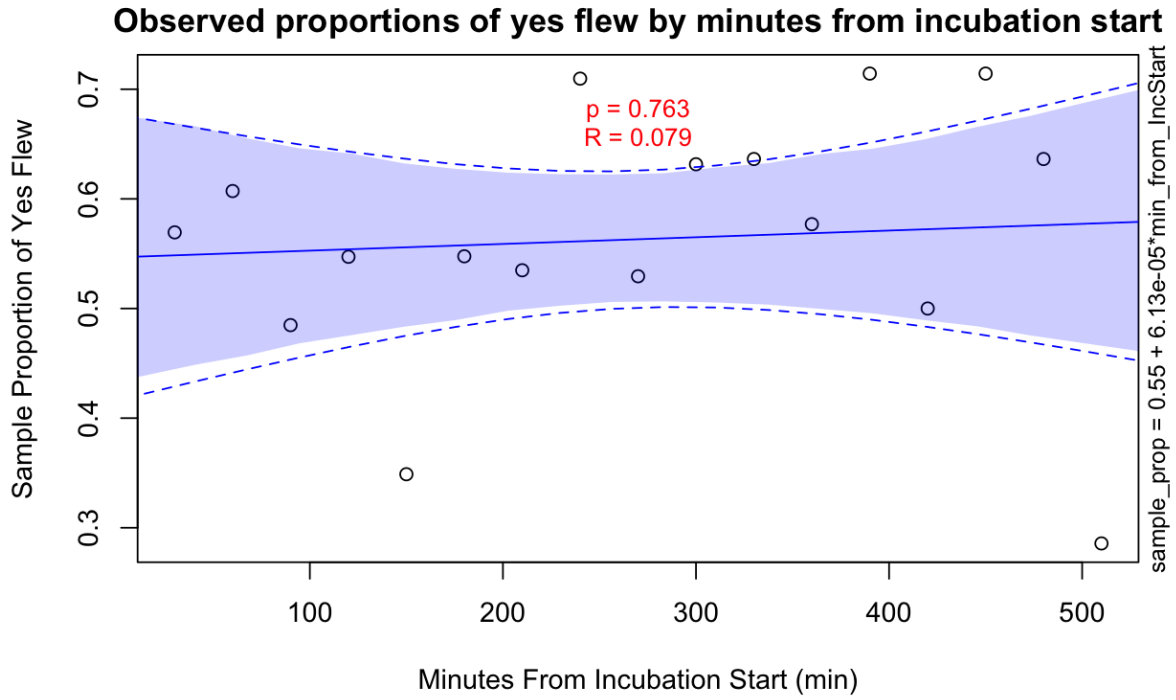

Mass (g)
0.04 0.06 0.08 0.10 0.12 0.14
9 10 11 12 13 14
Body (mm)

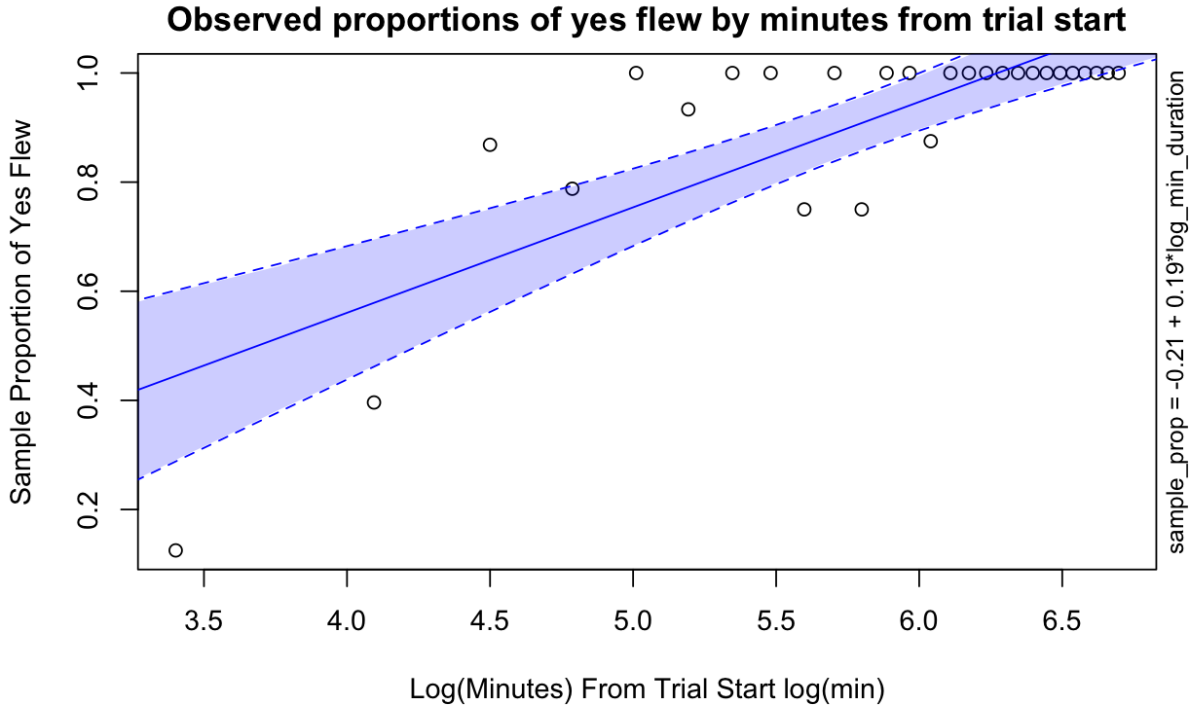

Mass (g)
0.04 0.06 0.08 0.10 0.12 0.14
5 6 7 8 9 10
Beak (mm)

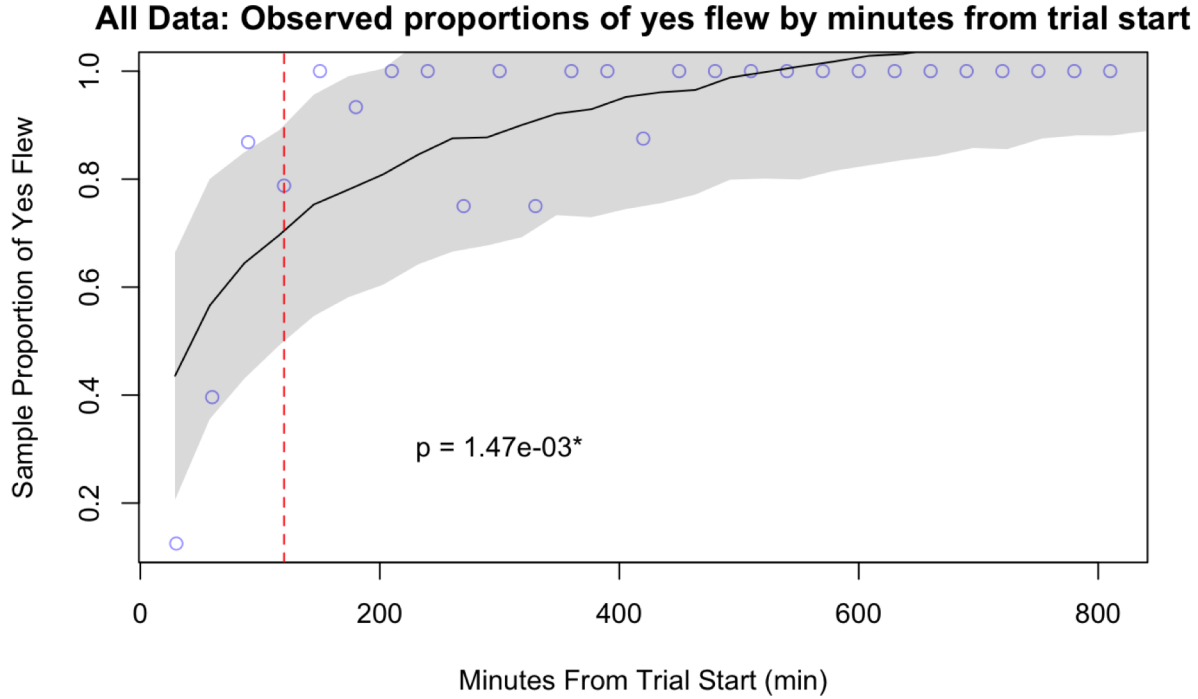

Mass (g)
0.04 0.06 0.08 0.10 0.12 0.14
2.5 3.0 3.5 4.0
Throax (mm)

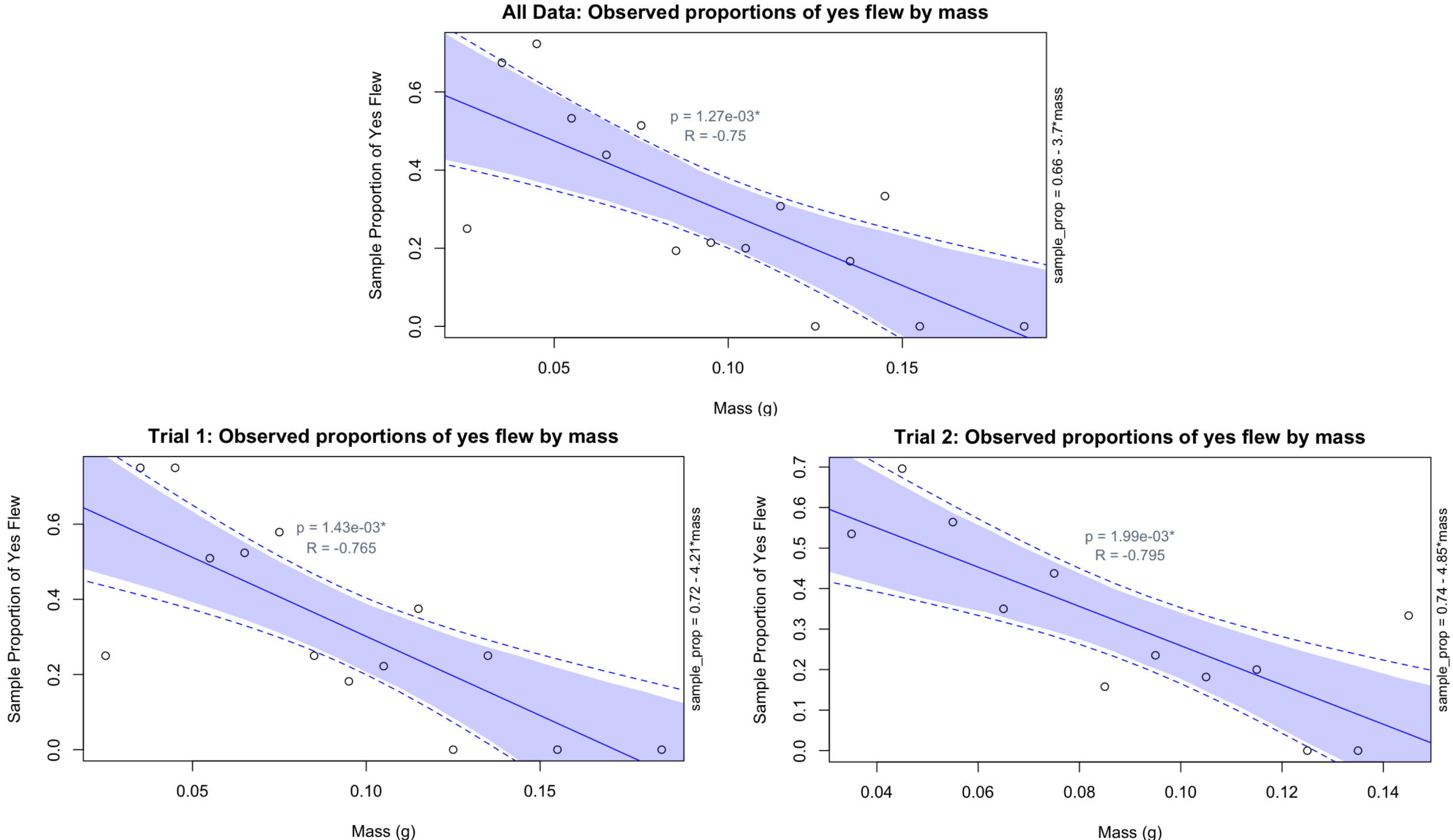

Mass (g)
0.04 0.06 0.08 0.10 0.12 0.14
6 7 8 9 10
Wing (mm)

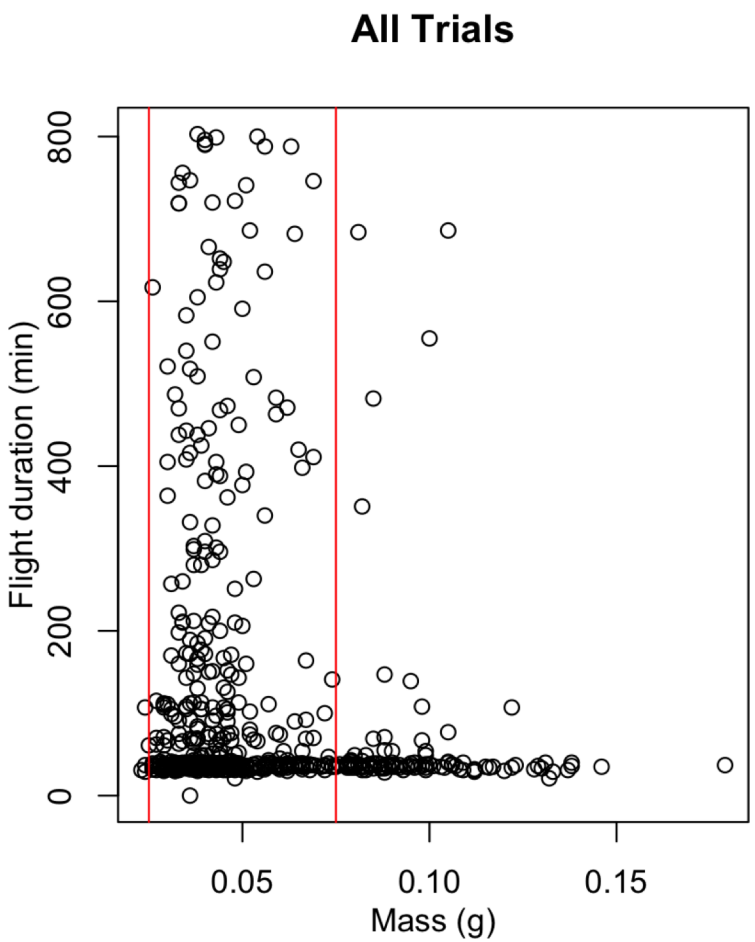
Yes-No Flight Modeling

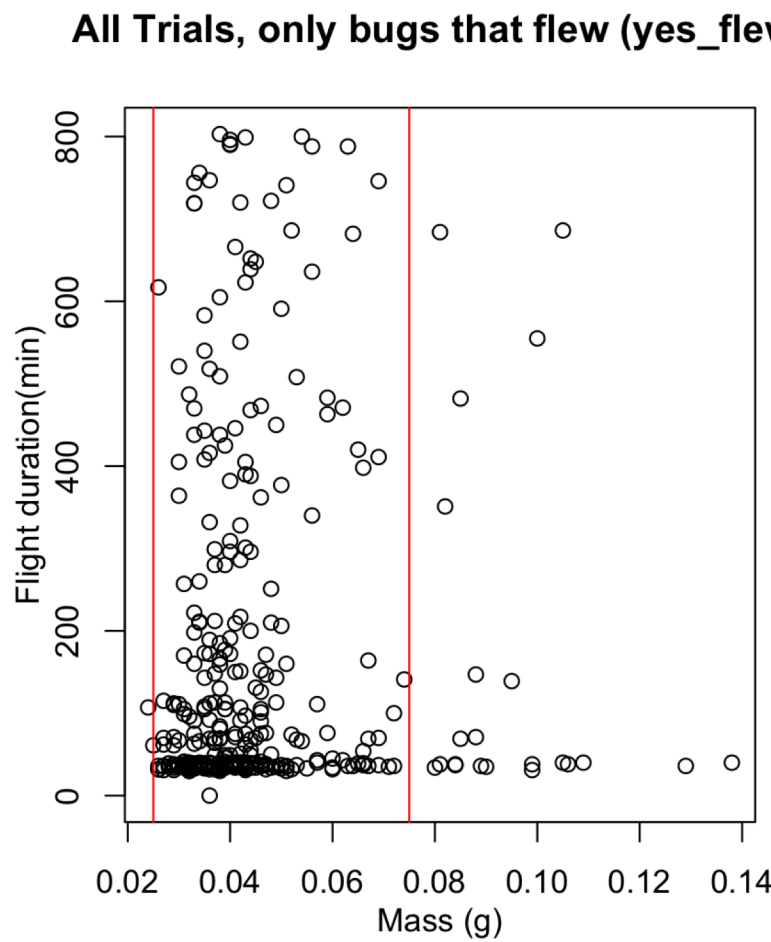

Observed proportions of yes flew by minutes from incubation start
p = 0.763
R = 0.079
Sample Proportion of Yes Flew
0.3
0.4
0.5
0.6
0.7
100
200
300
400
500
Minutes From Incubation Start (min)
sample_prop = 0.55 + 6.13e-05*min_from_IncStart

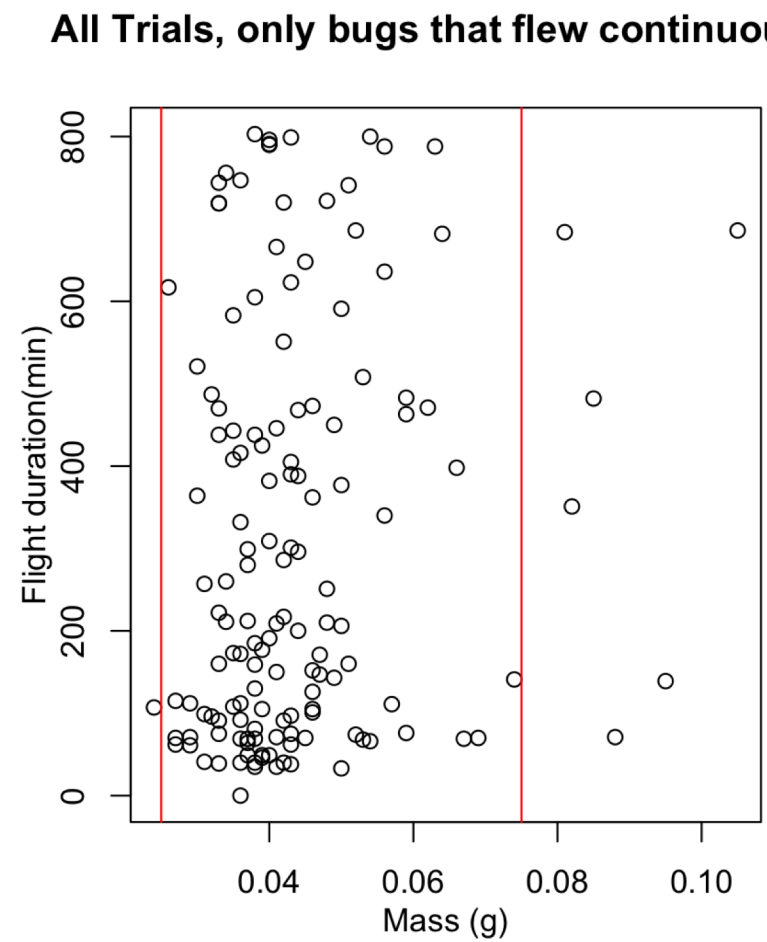

Observed proportions of yes flew by minutes from trial start
Sample Proportion of Yes Flew
0.2
0.4
0.6
0.8
1.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
Log(Minutes) From Trial Start log(min)
sample_prop = -0.21 + 0.19*log_min_duration


All Data: Observed proportions of yes flew by minutes from trial start
Sample Proportion of Yes Flew
0.2
0.4
0.6
0.8
1.0
p = 1.47e-03*
0
200
400
600
800
Minutes From Trial Start (min)

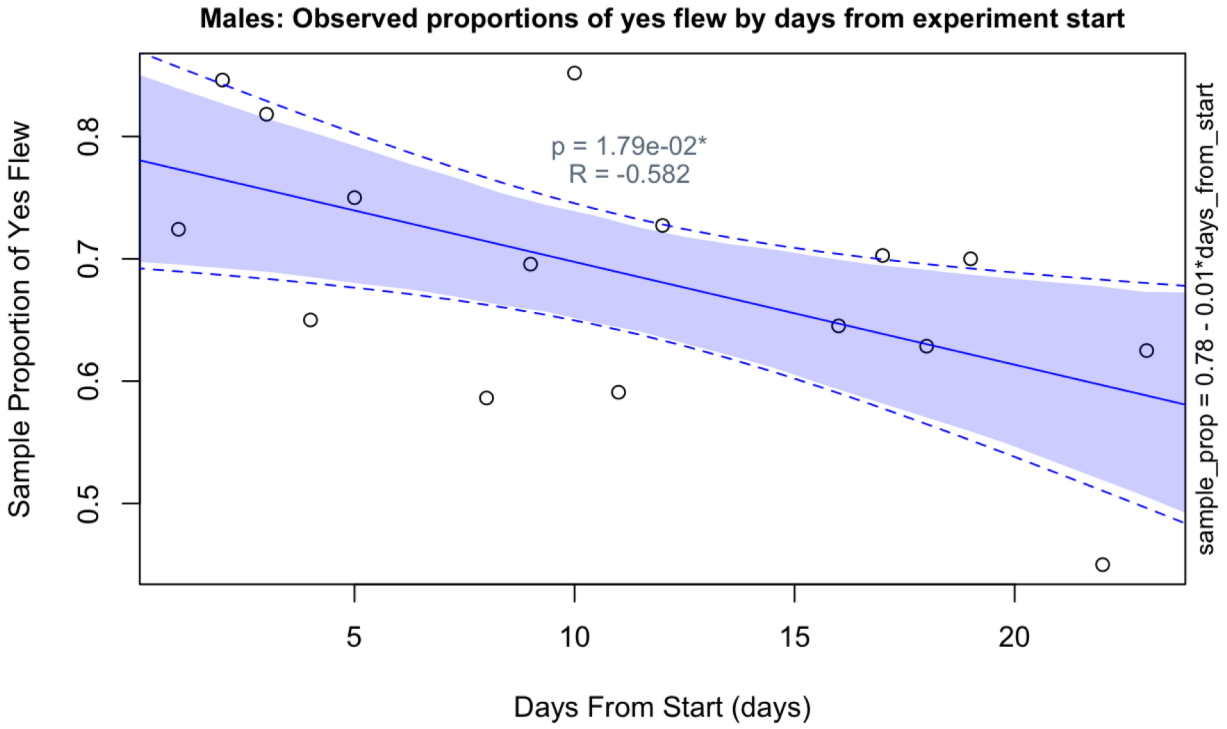

All Data: Observed proportions of yes flew by mass
Sample Proportion of Yes Flew
0.0
0.2
0.4
0.6
p = 1.27e-03*
R = -0.75
sample_prop = 0.66 - 3.7*mass
0.05
0.10
0.15
Mass (g)
Trial 1: Observed proportions of yes flew by mass
Sample Proportion of Yes Flew
0.0
0.2
0.4
0.6
p = 1.43e-03*
R = -0.765
sample_prop = 0.72 - 4.21*mass
0.05
0.10
0.15
Mass (g)
Trial 2: Observed proportions of yes flew by mass
Sample Proportion of Yes Flew
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
p = 1.99e-03*
R = -0.795
sample_prop = 0.74 - 4.85*mass
0.04
0.06
0.08
0.10
0.12
0.14
Mass (g)

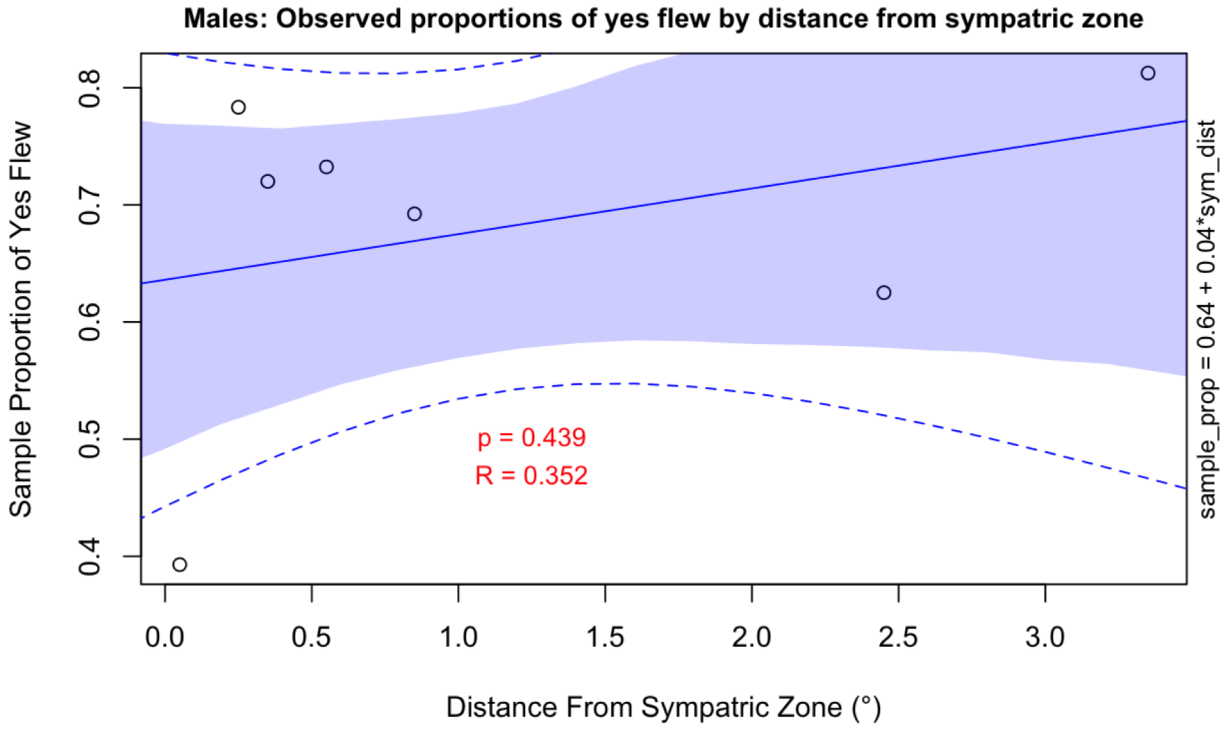

All Trials
Flight duration (min)
0
200
400
600
800
0.05
0.10
0.15
Mass (g)

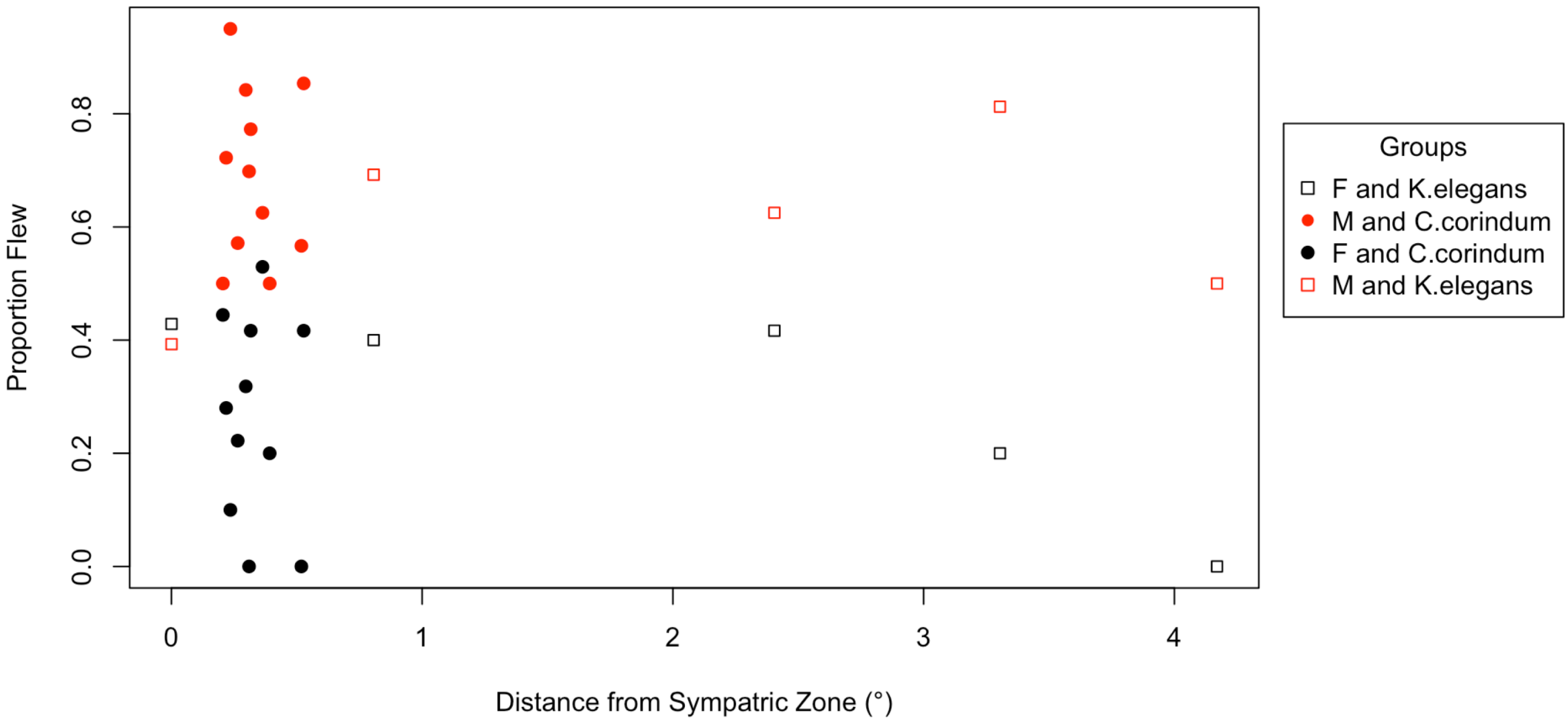

All Trials, only bugs that flew (yes_flew)
Flight duration(min)
0
200
400
600
800
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Mass (g)

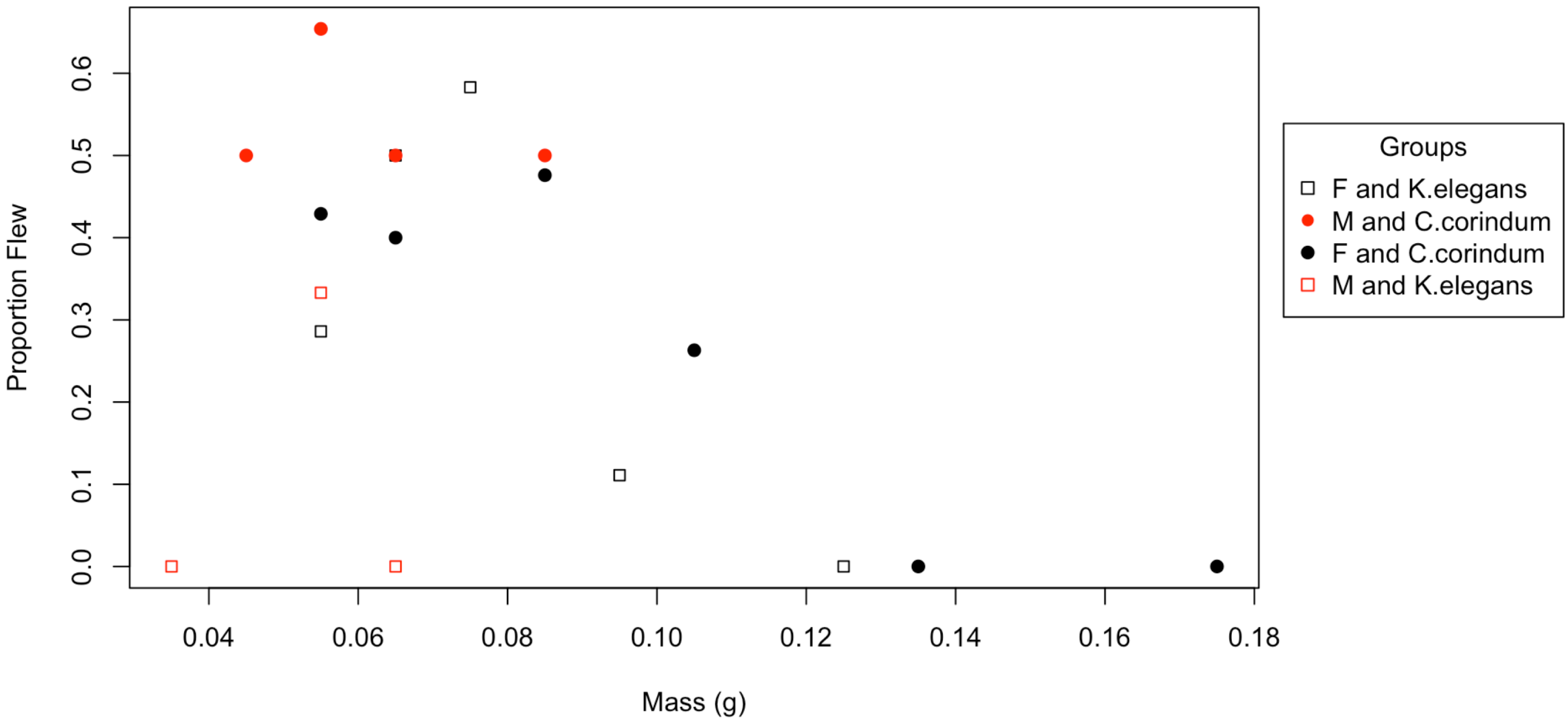

All Trials, only bugs that flew continuous
Flight duration(min)
0
200
400
600
800
0.04
0.06
0.08
0.10
Mass (g)

Males


Males: Observed proportions of yes flew by days from experiment start
Sample Proportion of Yes Flew
0.5
0.6
0.7
0.8
p = 1.79e-02*
R = -0.582
5
10
15
20
Days From Start (days)
sample_prop = 0.78 - 0.01*days_from_start


Males: Observed proportions of yes flew by distance from sympatric zone
Sample Proportion of Yes Flew
0.4
0.5
0.6
0.7
0.8
p = 0.439
R = 0.352
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Distance From Sympatric Zone (°)
sample_prop = 0.64 + 0.04*sym_dist


All Observed Data: sex*host_plant*sym_dist
Proportion Flew
0.0
0.2
0.4
0.6
0.8
0
1
2
3
4
Distance from Sympatric Zone (°)
Groups
F and K.elegans
M and C.corindum
F and C.corindum
M and K.elegans


All Observed Data: prop_flew ~ mass*host*sex
Proportion Flew
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
Mass (g)
Groups
F and K.elegans
M and C.corindum
F and C.corindum
M and K.elegans

All Data:

- Effect of test date (but no effect of test date when you split between T1 and T2)
- (Strong) Effect of mass
- Effect of beak length - - F yes, M no
- Effect of thorax length
- Effect of body length - F yes, M no
- No effect of wing length – except when you split by sexes

Females

- Effect of number of eggs laid - * Strong negative effect if laid eggs that day
- Effect of whether eggs were laid or not
- After mass:
  - *Large effect of mass

Males

- Effect of test date
- Before mass:
  - * Strong negative effect if from GRT
- After mass:
  - * Strong negative effect if from GRT
  - * Strong negative effect of mass, that if weigh more then less likely to disperse

By Trial

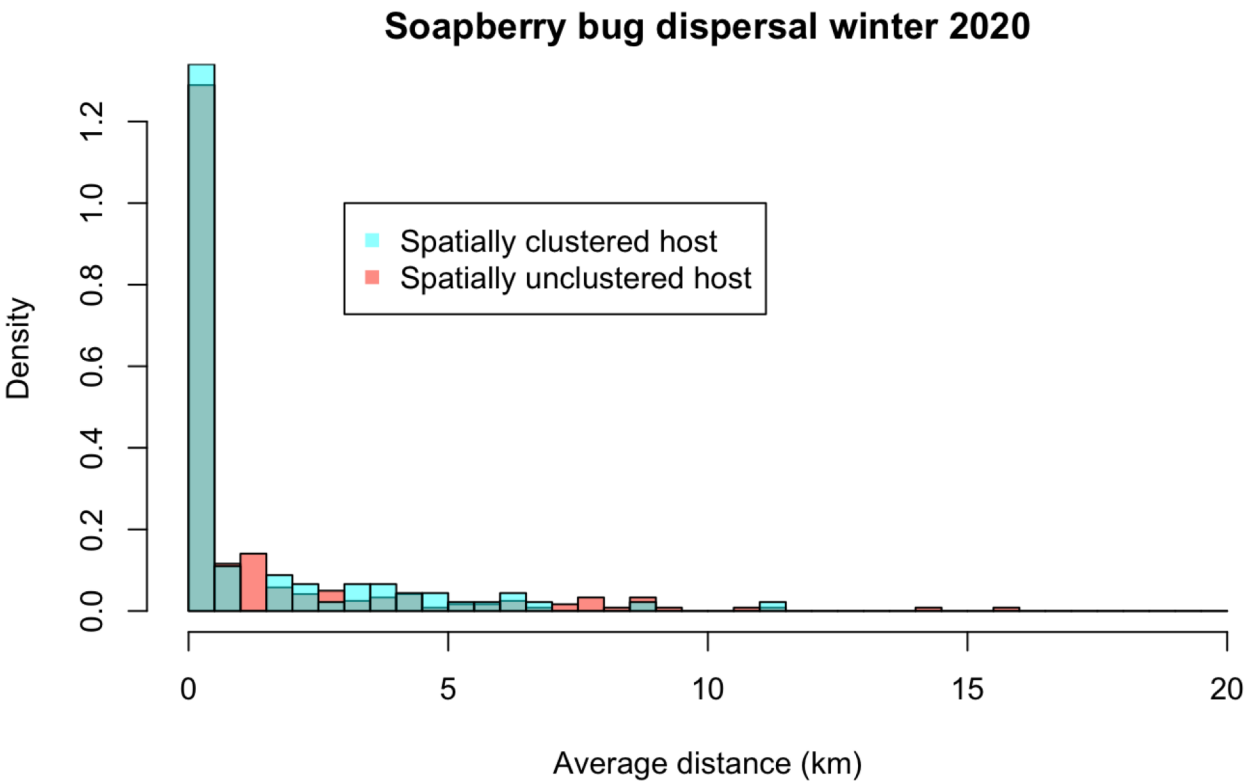
TI:

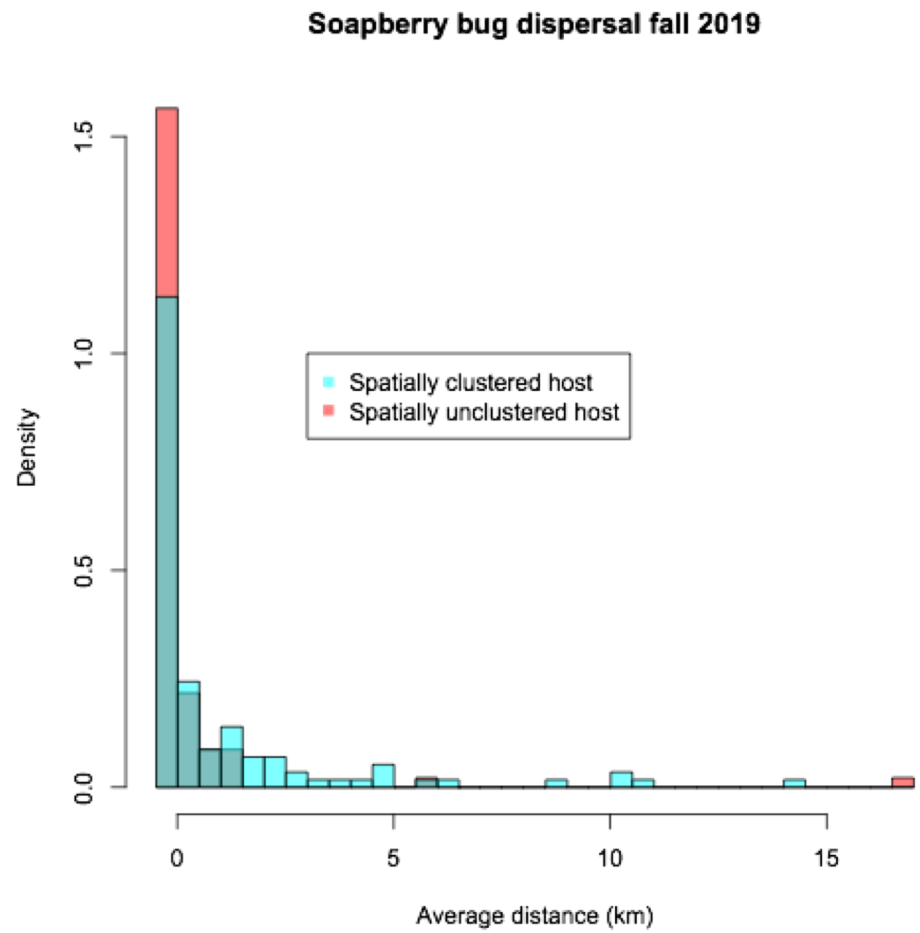
- Before add mass:
  - * strong negative effect of sex, where if you are female you are less likely to fly.
  - * no longer an effect of host or distance from sympatric zone. (last season there was)
  - * strong interaction between sex and host where if female and from GRT, then less likely to fly.
- After add mass:
  - * no effect of host plant
  - * strong negative effect of mass and has a large coefficient, where the heavier the bug is the much less likely the bug will fly.
  - * host*sex interaction shows a strong positive effect, such that if from GRT and are female then more likely to be dispersive
  - * marginal effect of sex, where if you are female you are less likely to fly

T2:

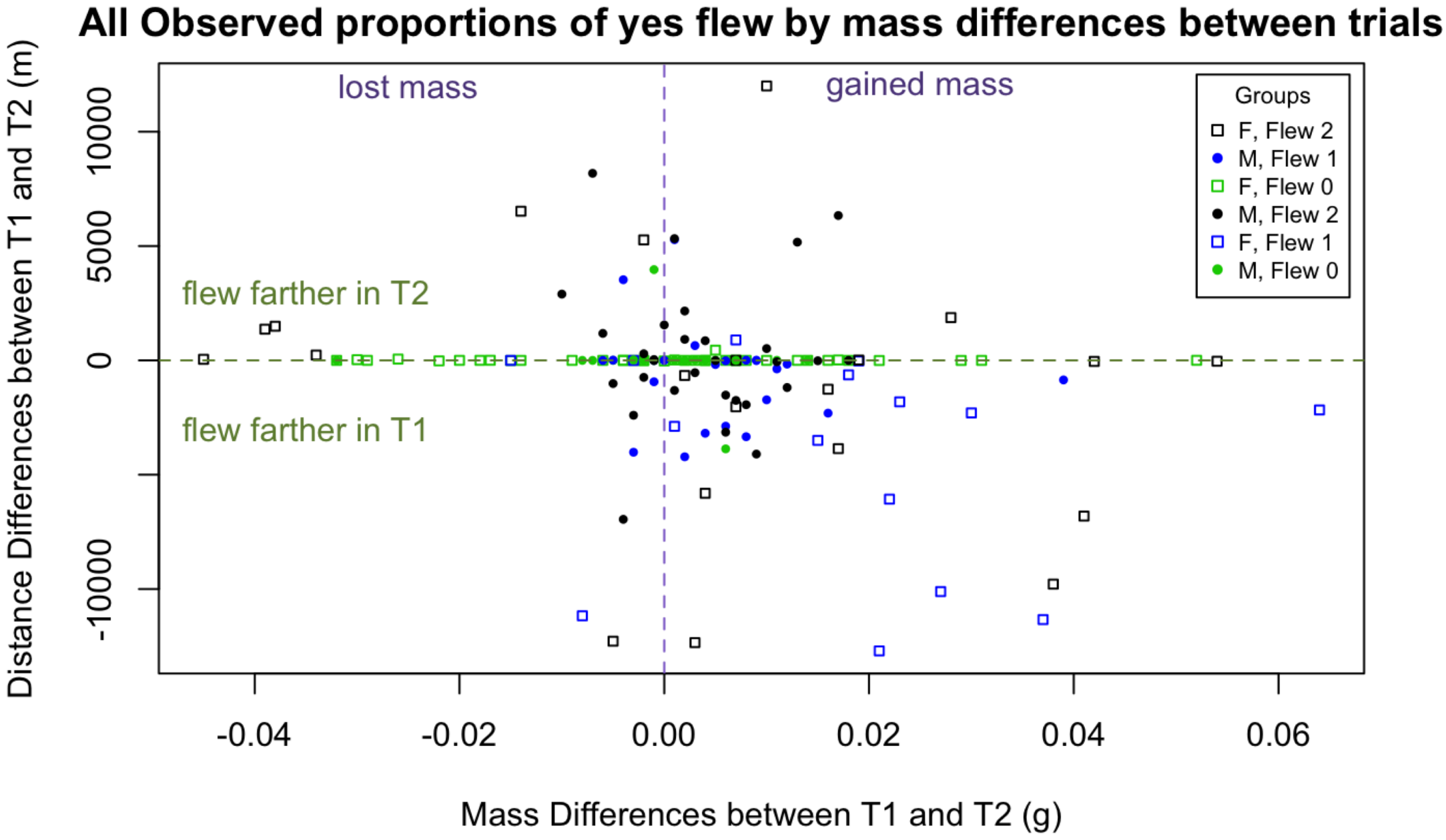
- Before add mass:
  - * sex is the only significant and strong effect, so that if you are female you are much less likely to disperse/fly
- After add mass:
  - * mass is the only significant and extremely strong effect, so that if you are heavy you are much less likely to disperse/fly

Speed and Distance

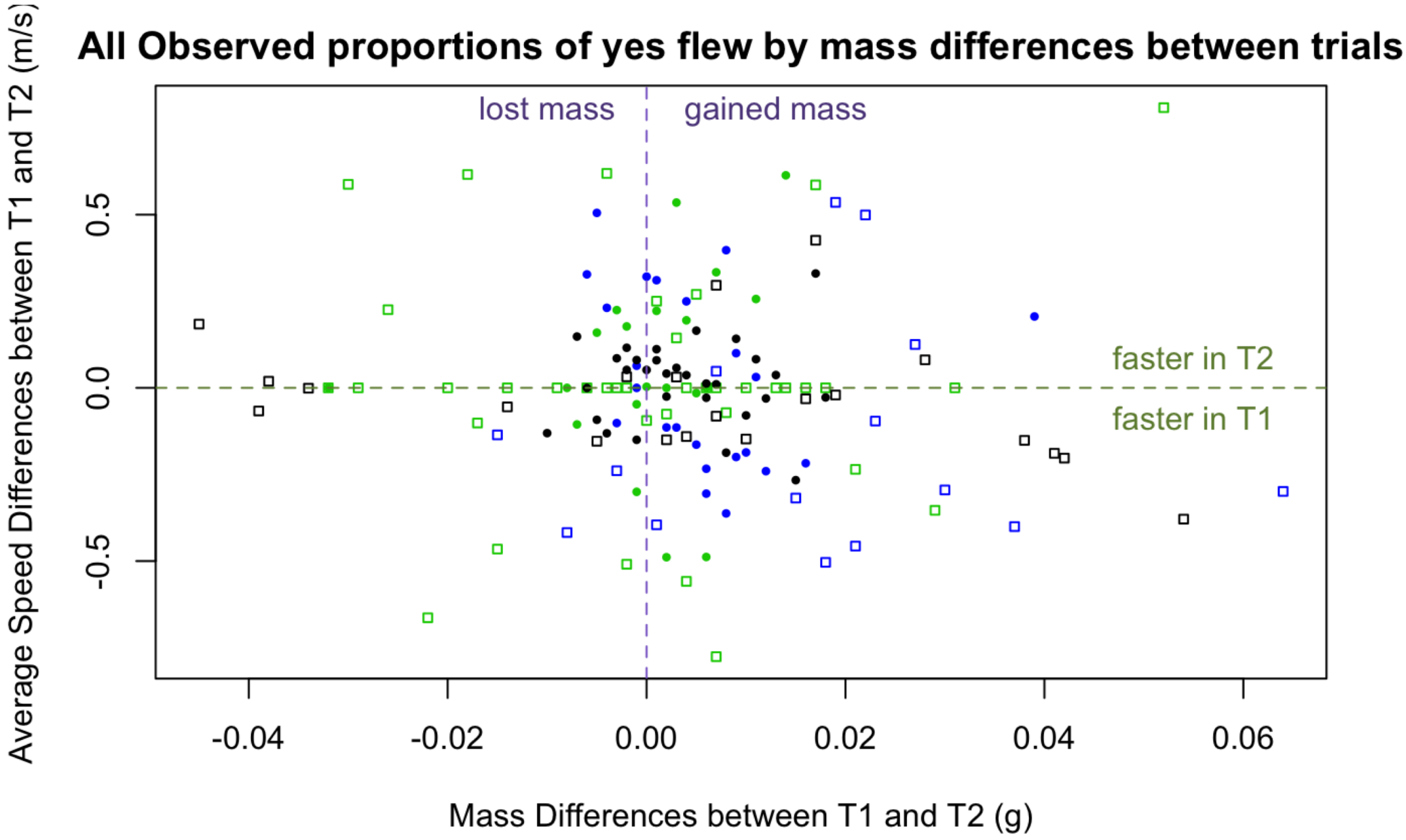

Soapberry bug dispersal winter 2020
Density
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Spatially clustered host
Spatially unclustered host
0
5
10
15
20
Average distance (km)

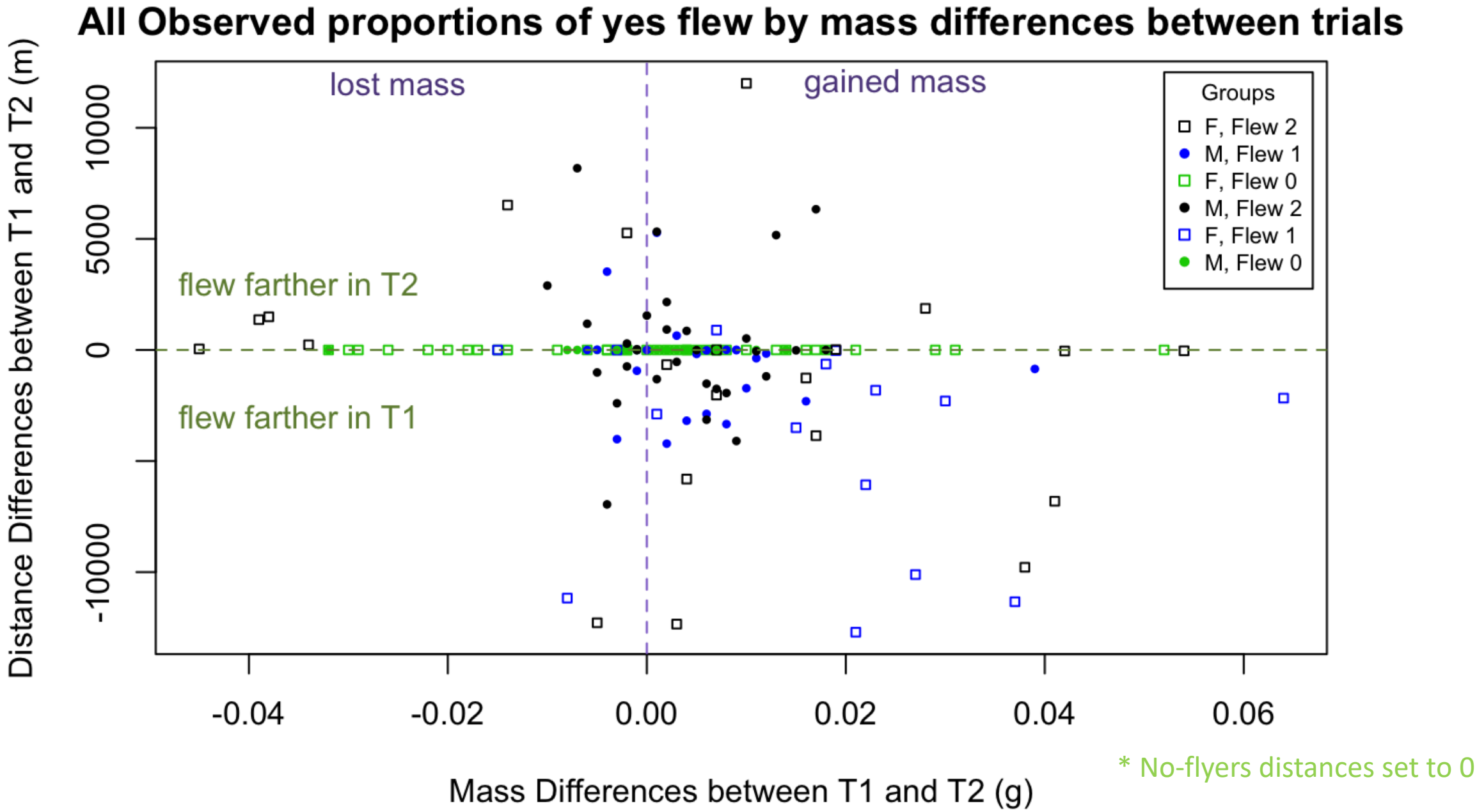

Soapberry bug dispersal fall 2019
Density
0.0
0.5
1.0
1.5
Spatially clustered host
Spatially unclustered host
0
5
10
15
Average distance (km)

Problem:
False readings from no-flyers?

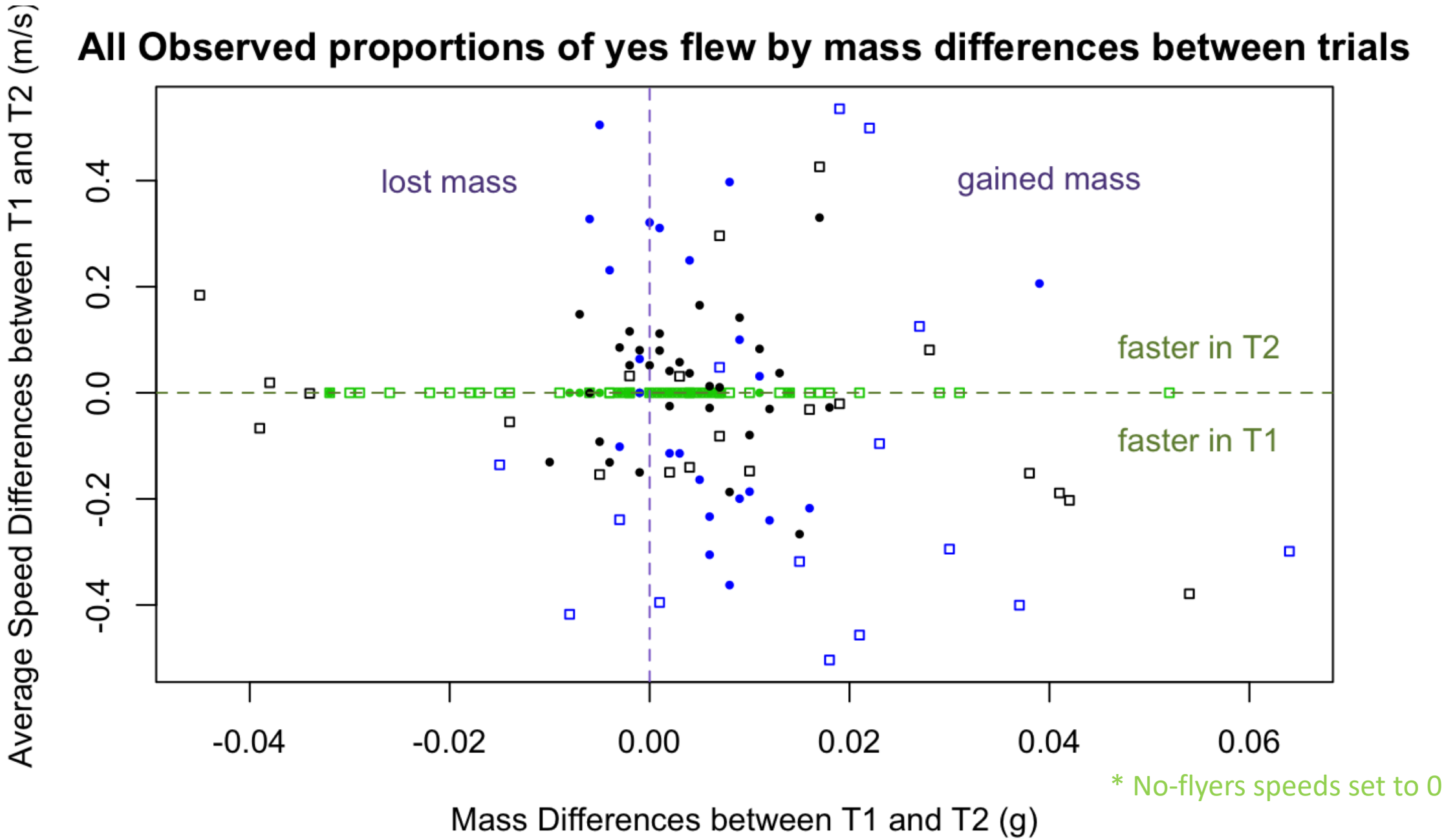


Problem:
False readings from no-flyers?

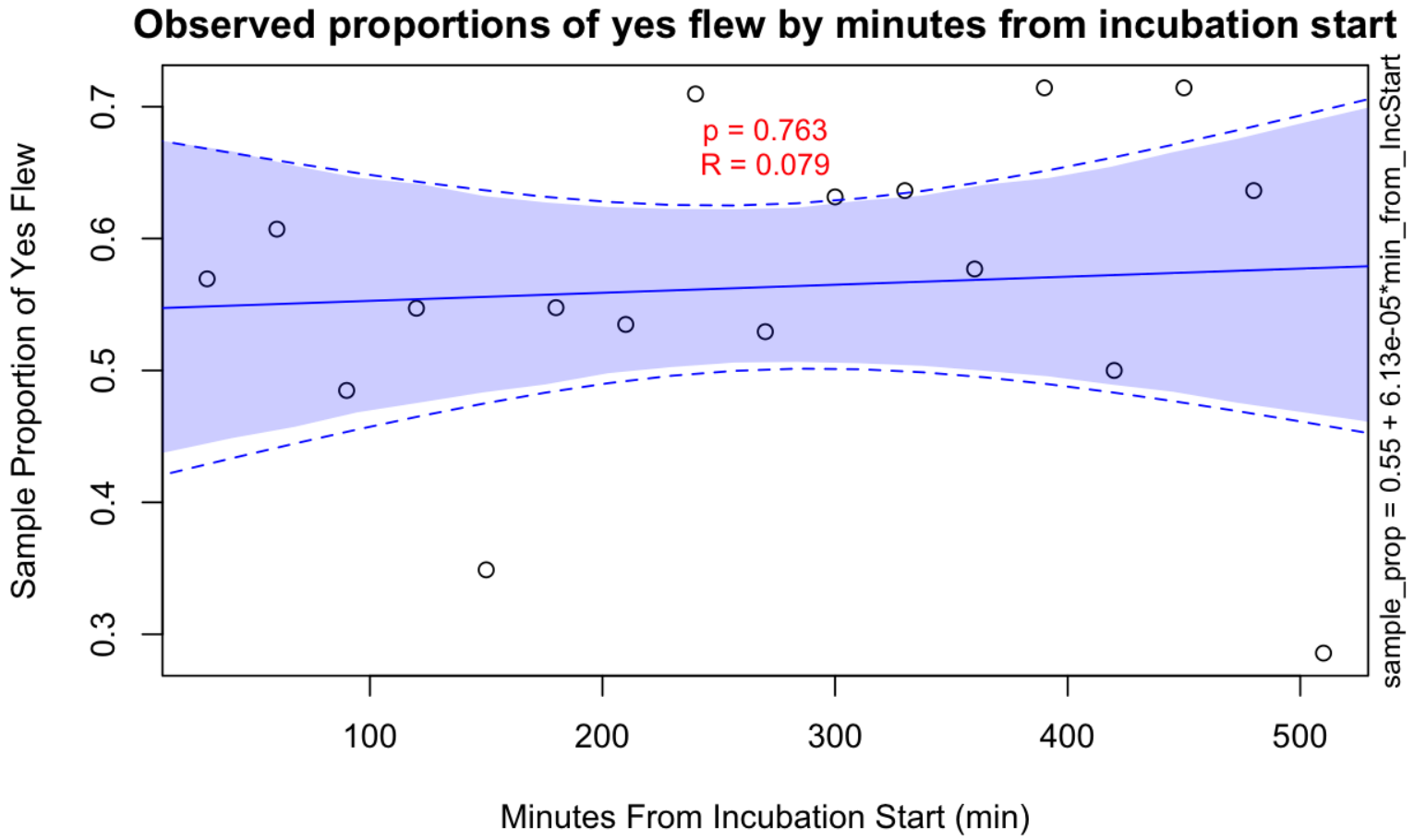




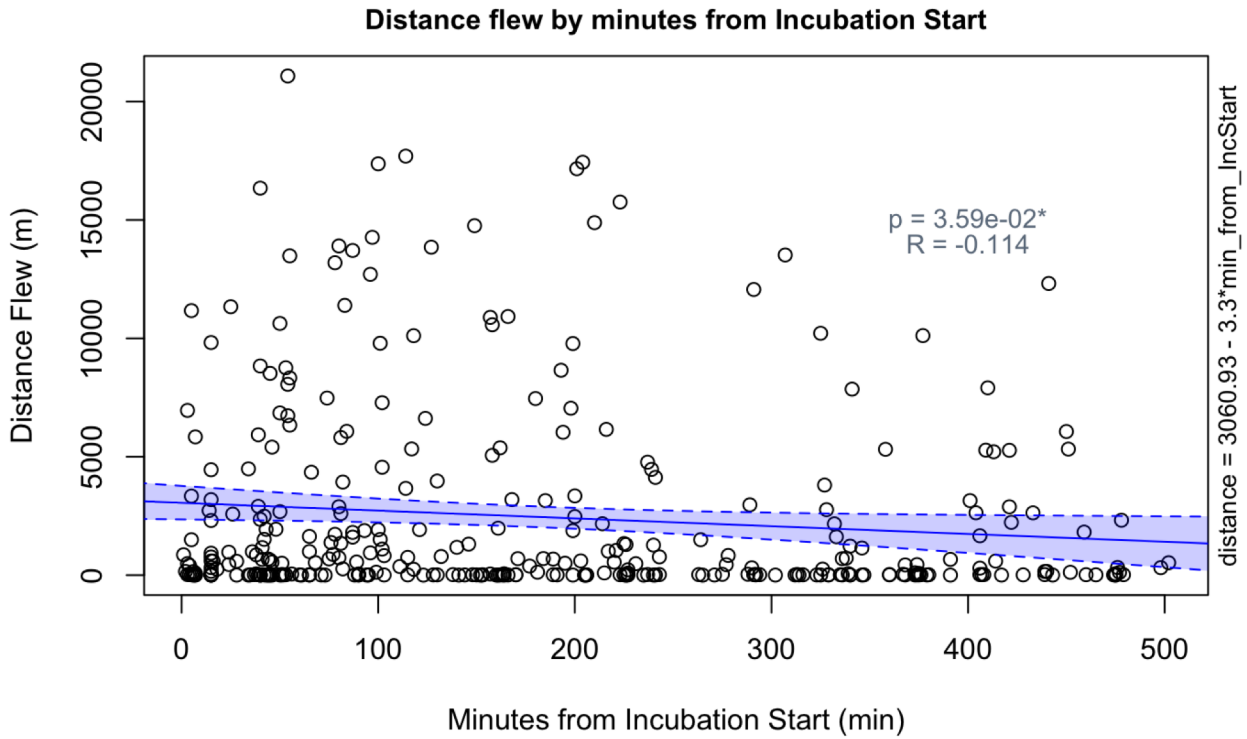
* No-flyers distances set to 0

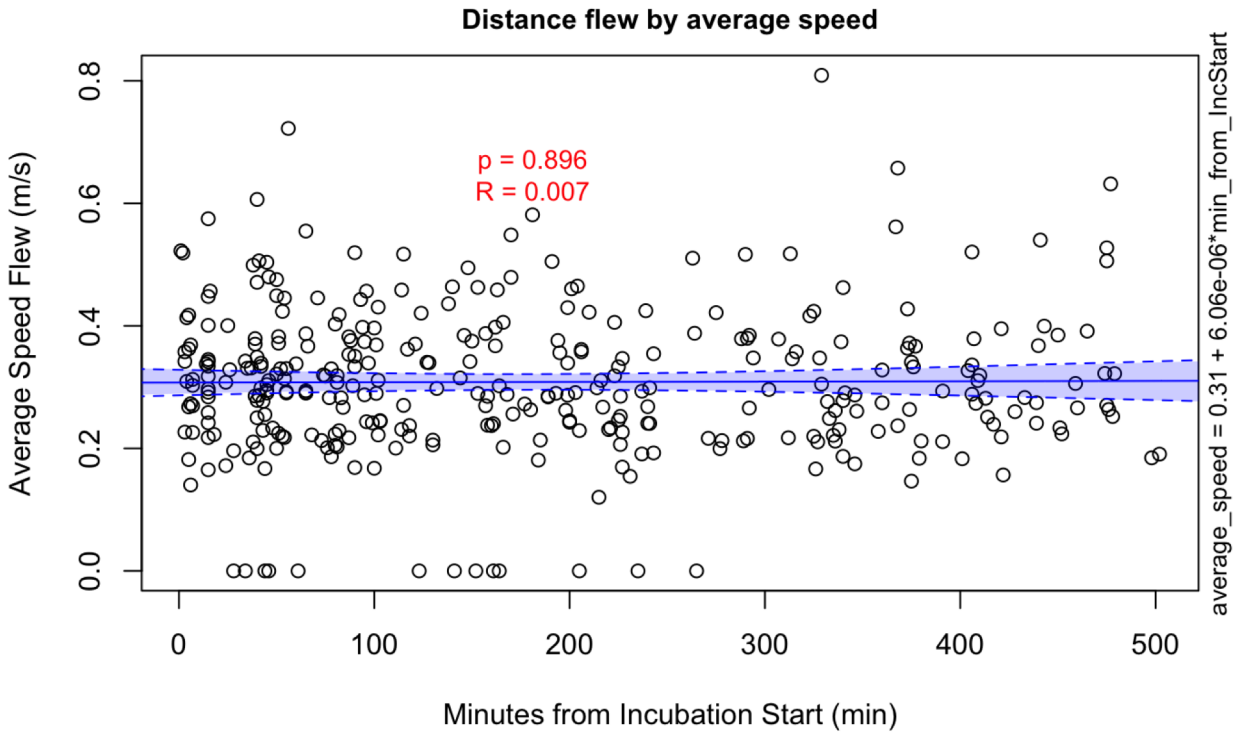

All Observed proportions of yes flew by mass differences between trials
Average Speed Differences between T1 and T2 (m/s)
0.4
0.2
0.0
-0.2
-0.4
lost mass
gained mass
faster in T2
faster in T1
-0.04
-0.02
0.00
0.02
0.04
0.06
Mass Differences between T1 and T2 (g)
* No-flyers speeds set to 0

- Distances and average speeds could be effected by different times of day.
  - Shorter distance and faster average speeds if tested post-noon
  - Longer distance and slower average speeds if tested pre-noon



- Distances and average speeds could be effected by different times of day.
  - Shorter distance and faster average speeds if tested post-noon?
  - Longer distance and slower average speeds if tested pre-noon?





- When bug starts flying in the day, does not affect average speed flew.
- When bug starts flying in the day, does affect distance flew. Negative relationship.

* No-flyers were removed

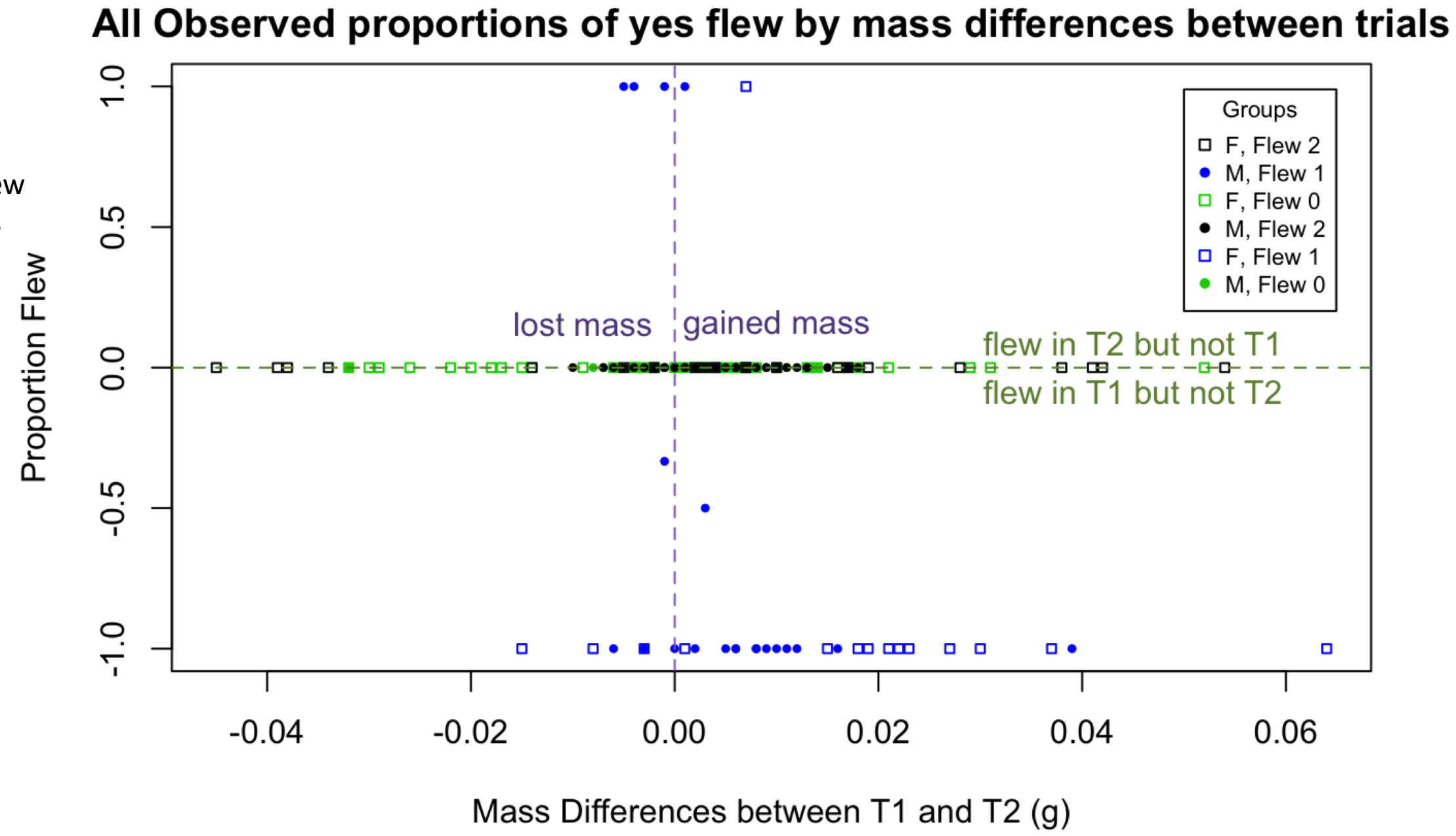
TBC…

- Need to consider whether the bugs who flew in one trial or not the other, are the change in distances because the change in mass or the change in time of testing?

- Speed over time graph of individual bugs
  - Try to see if cluster by mass or some other variable
  - Can also get acceleration graphs this way, especially for long-distance flyers to see potential deceleration through time.

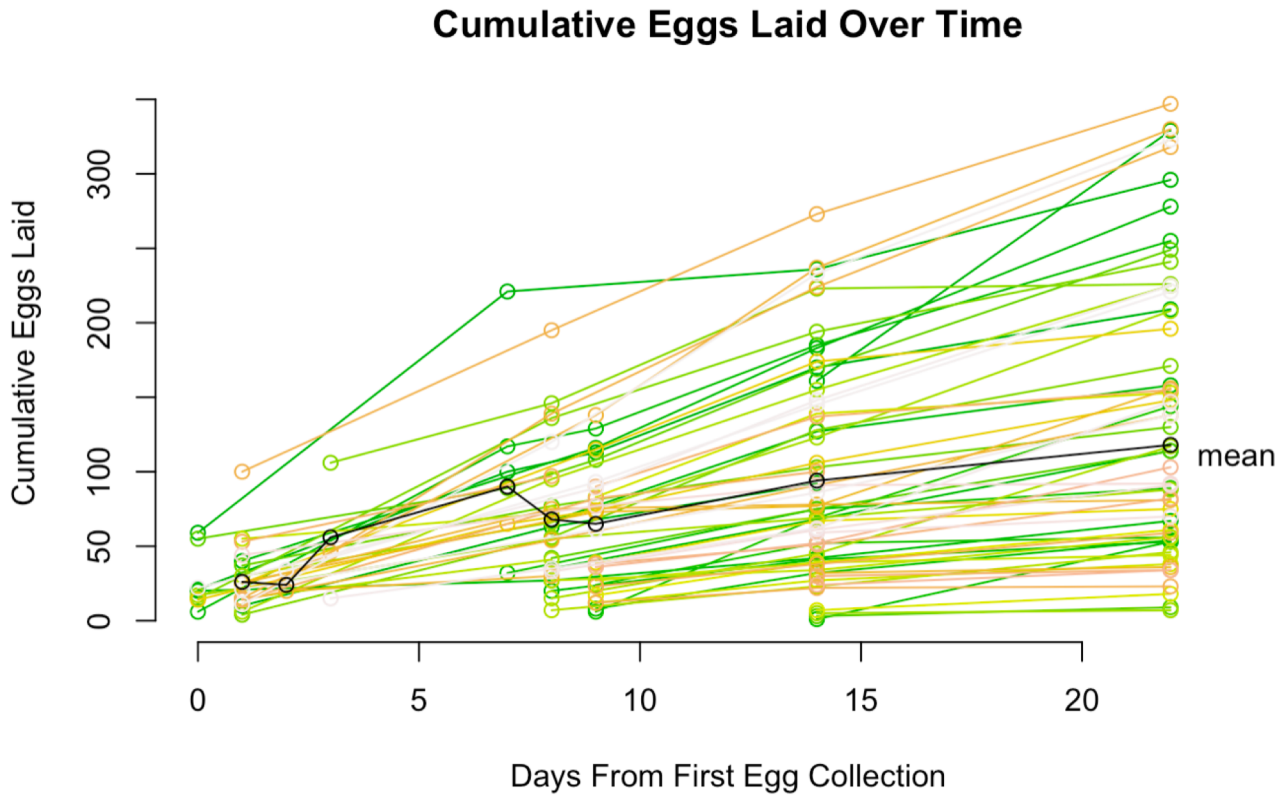
Changes in Mass

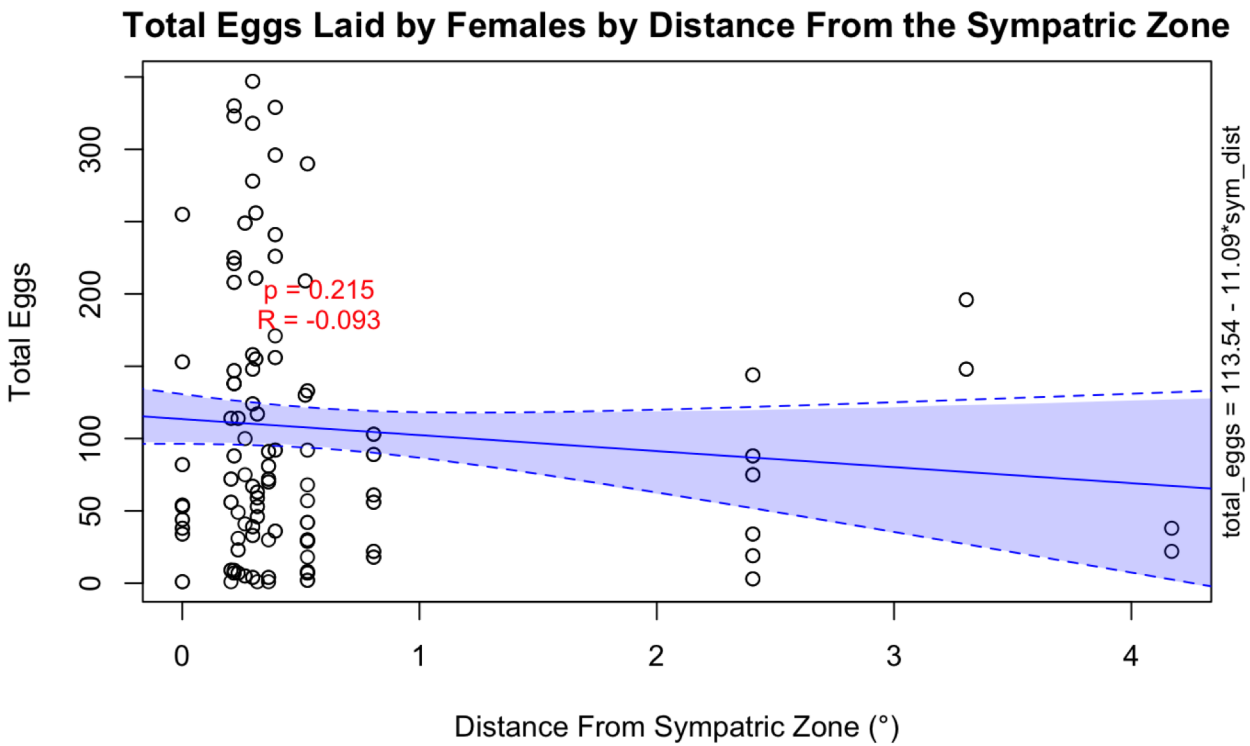
*Selected bugs who flew in both trials

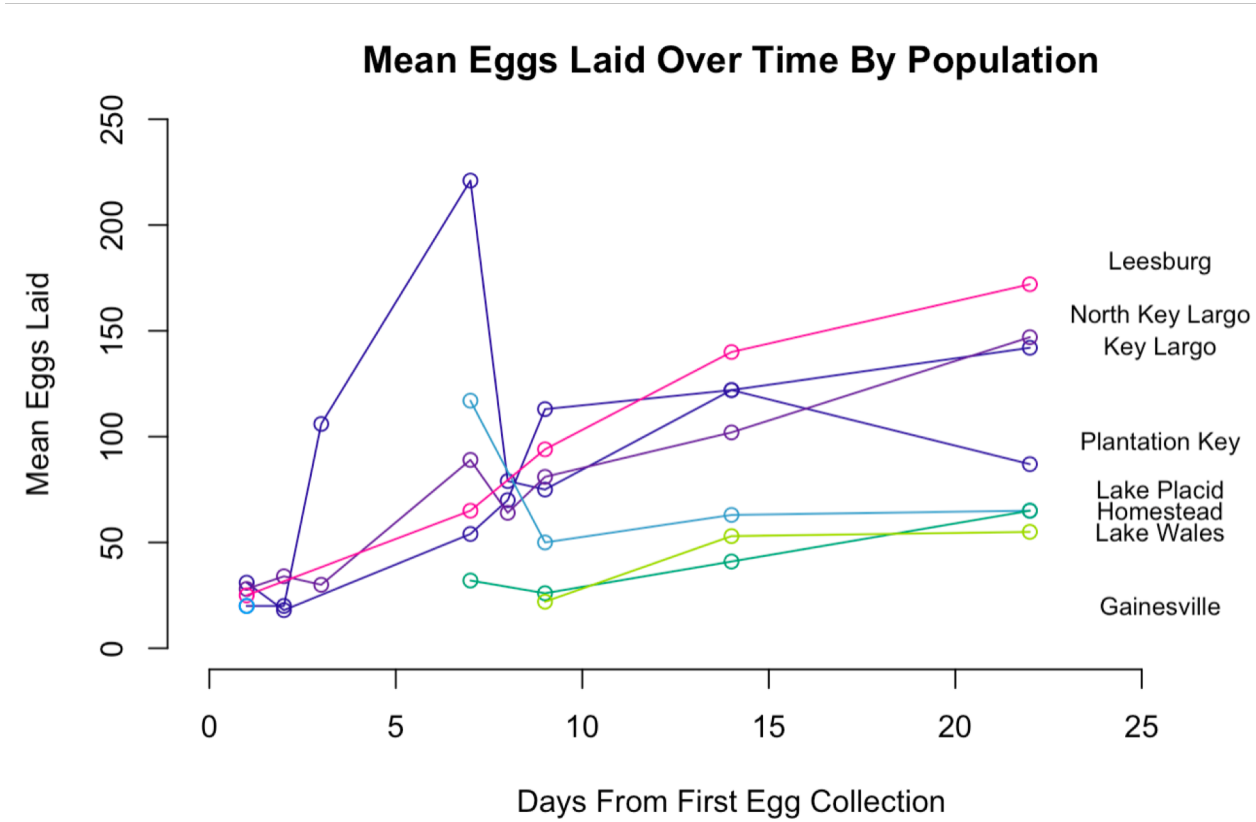


Eggs


Total Eggs Laid by Females by Mass
Total Eggs
0
50
100
200
300
p = 1.67e-09*
R = 0.429
0.05
0.10
0.15
Mass (g)

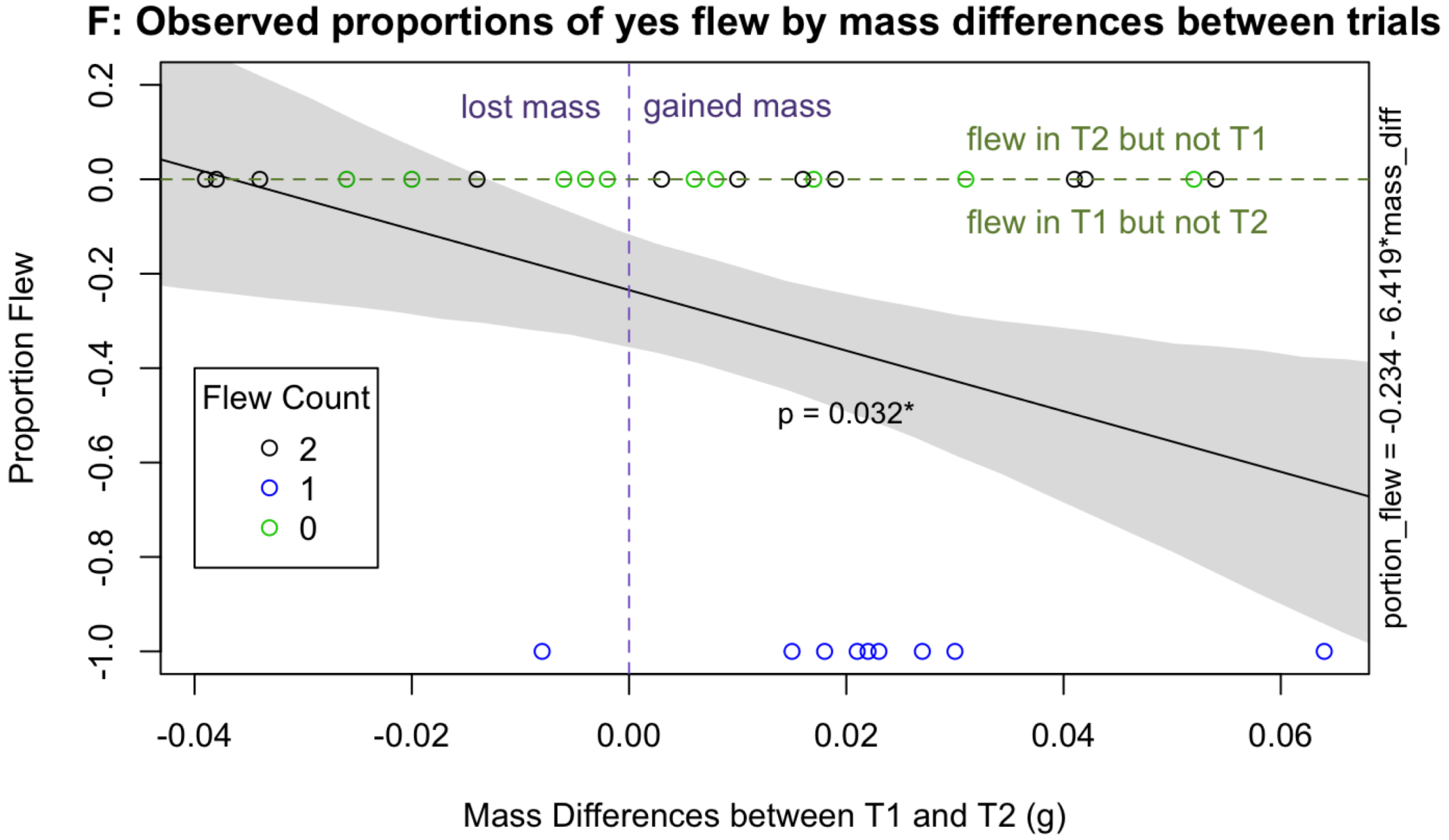

Cumulative Eggs Laid Over Time
Cumulative Eggs Laid
0
50
100
200
300
mean
0
5
10
15
20
Days From First Egg Collection


Total Eggs Laid by Females by Distance From the Sympatric Zone
Total Eggs
0
50
100
200
300
p = 0.215
R = -0.093
0
1
2
3
4
Distance From Sympatric Zone (°)
total_eggs = 113.54 - 11.09*sym_dist


Mean Eggs Laid Over Time By Population
Mean Eggs Laid
0
50
100
150
200
250
0
5
10
15
20
25
Days From First Egg Collection
Leesburg
North Key Largo
Key Largo
Plantation Key
Lake Placid
Homestead
Lake Wales
Gainesville

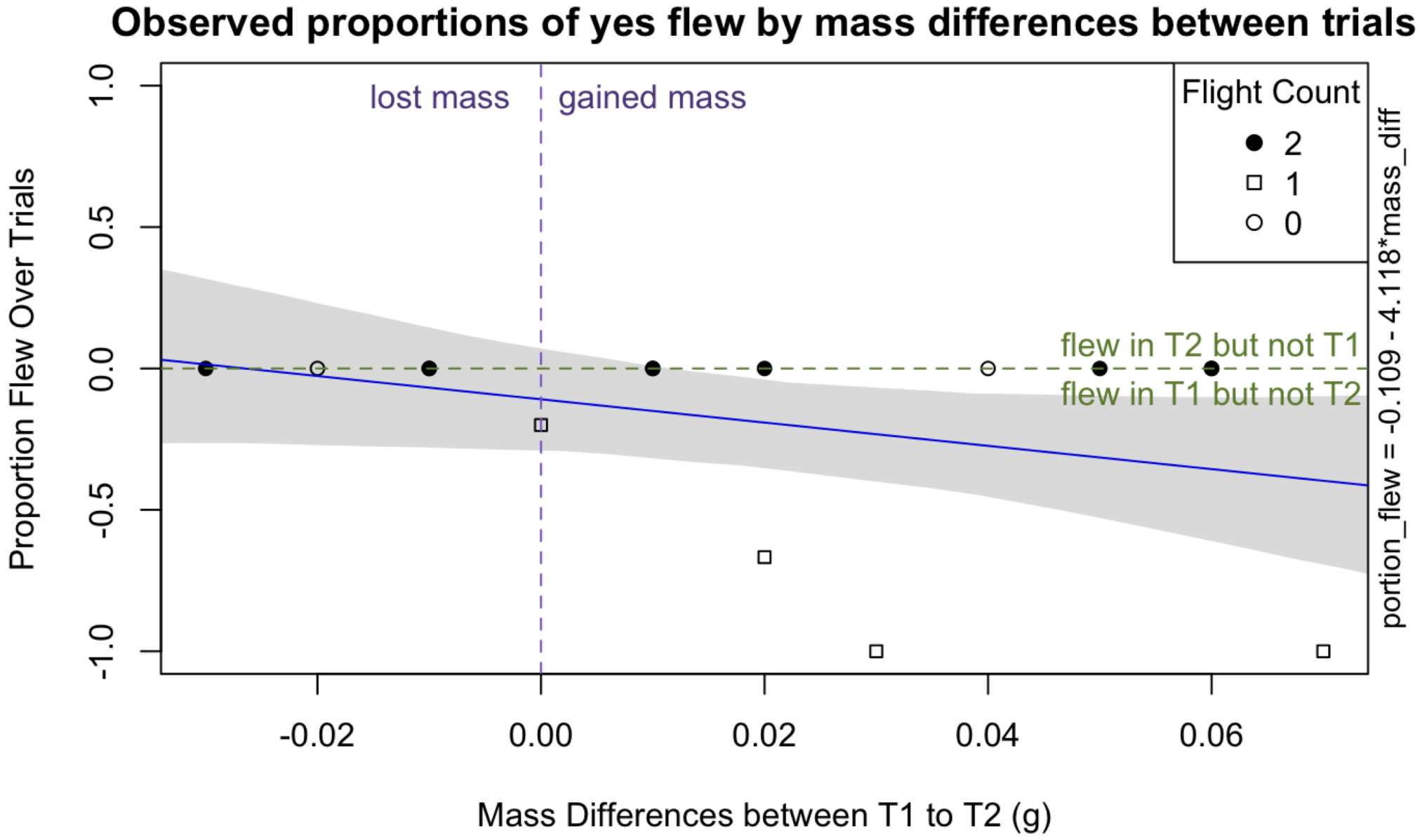
Females

*Selected females who flew in both trials *and* had different eggs laying responses between trials.



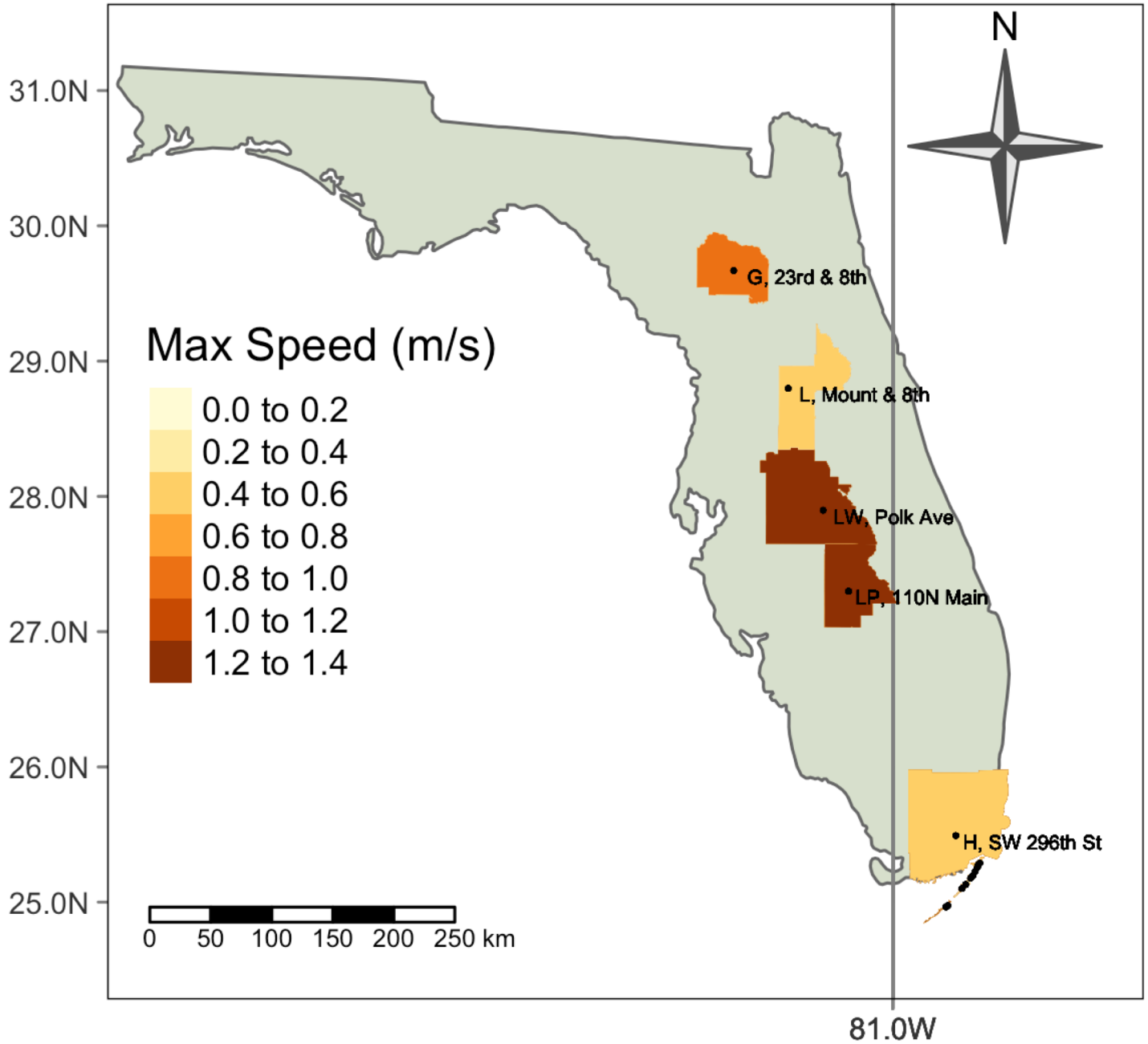
Females

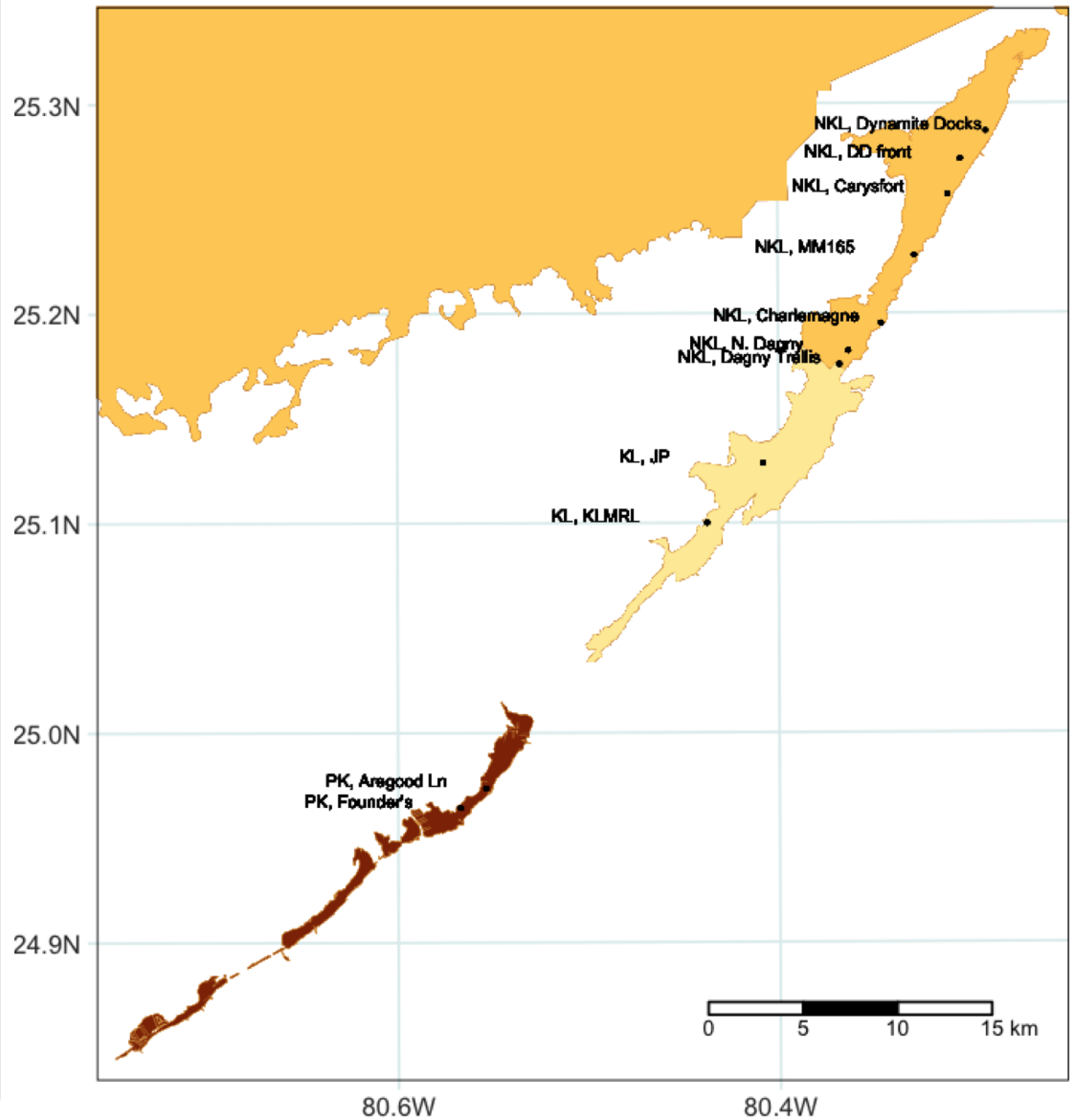
*Selected females who flew in both trials *and* had different eggs laying responses between trials.



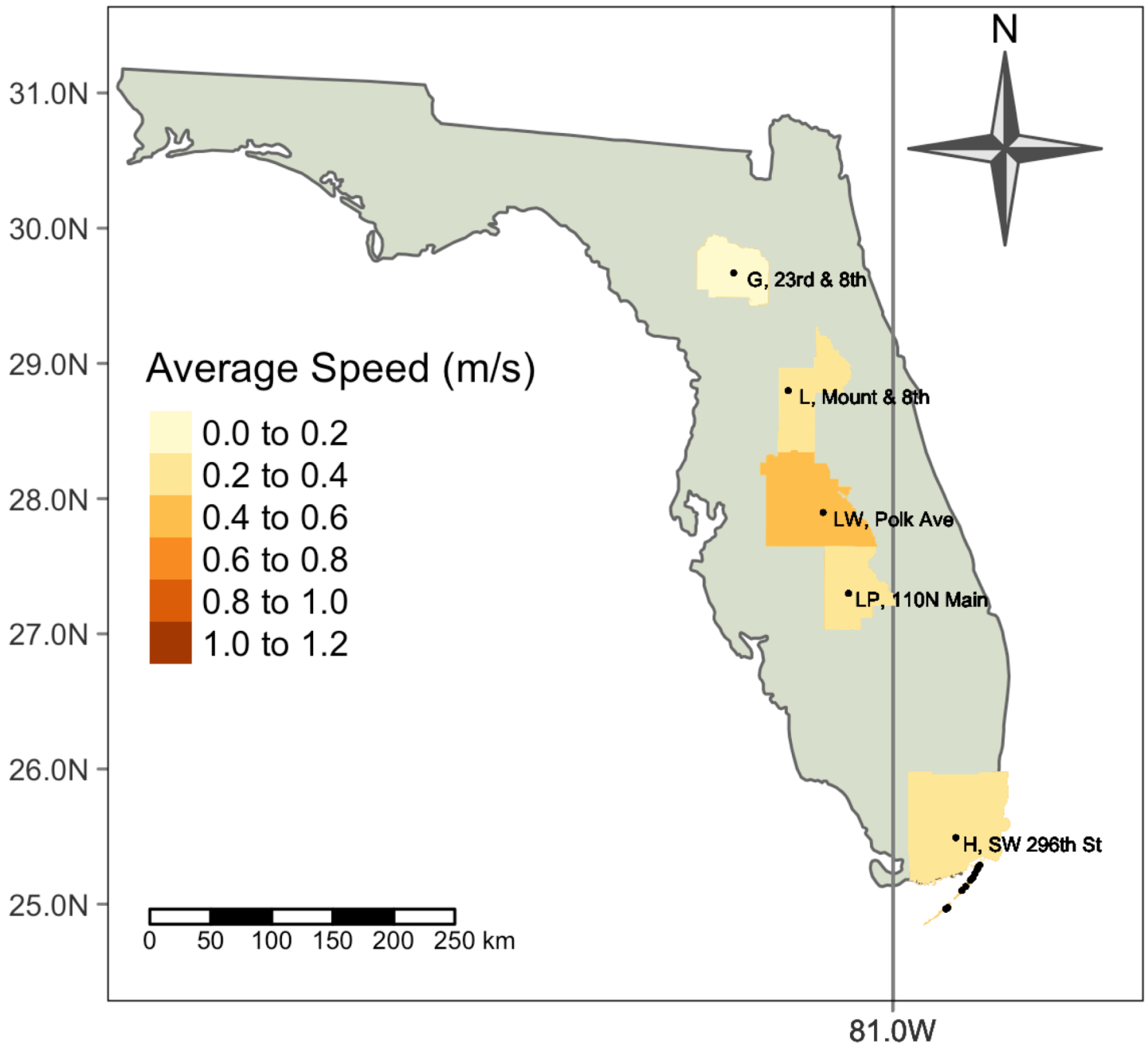
Maps

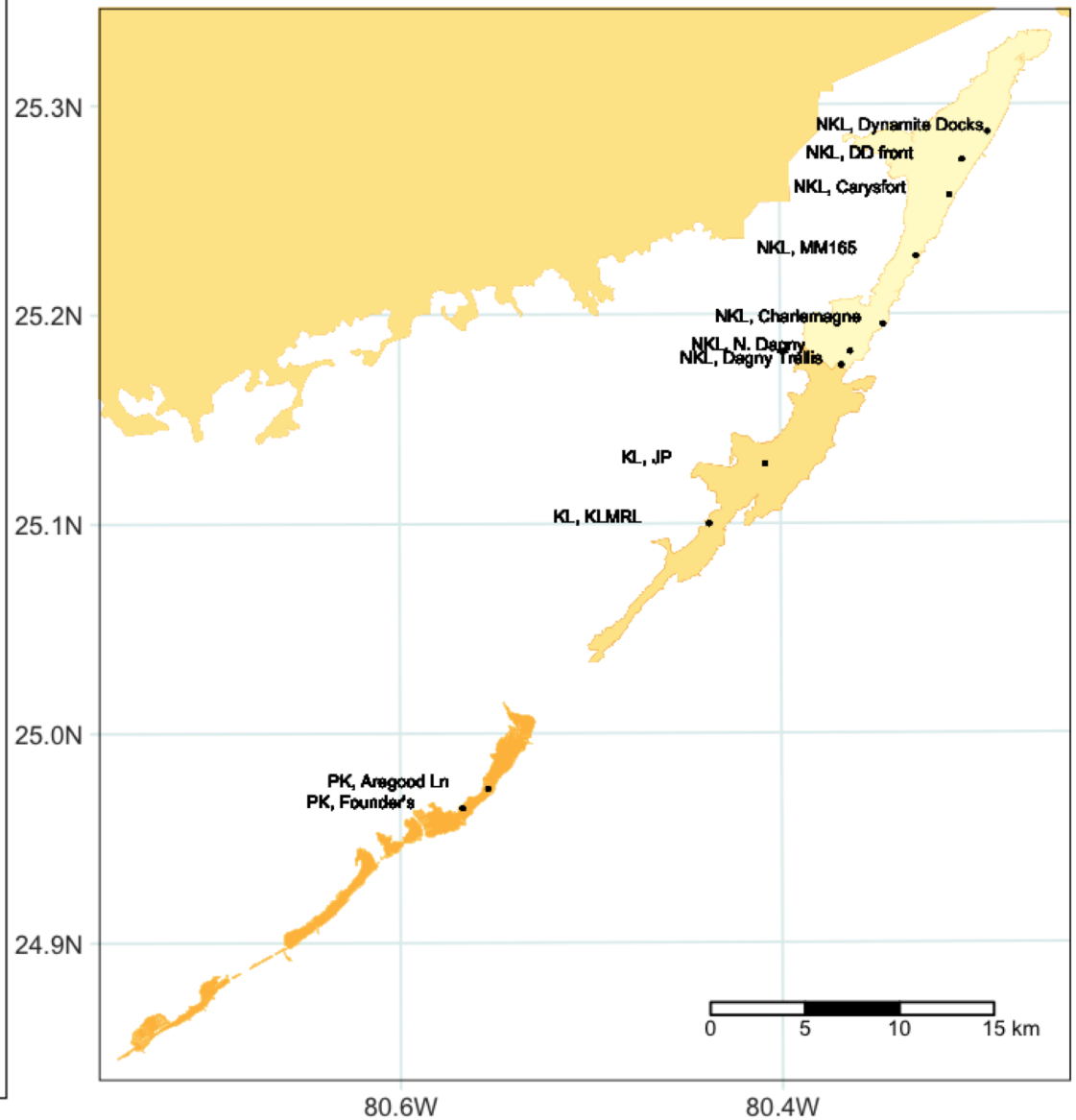
Max Flight Speed Across Latitude



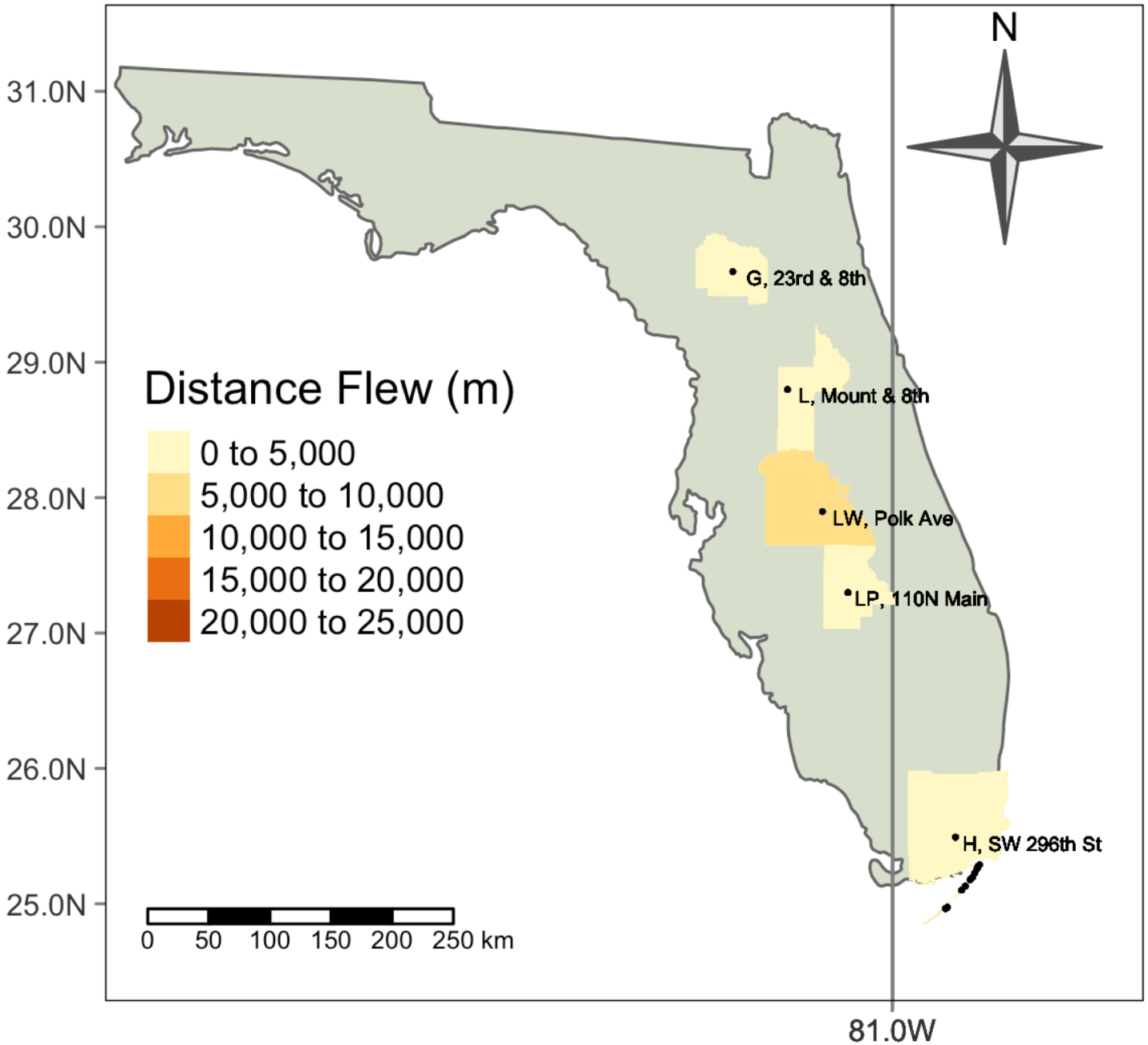


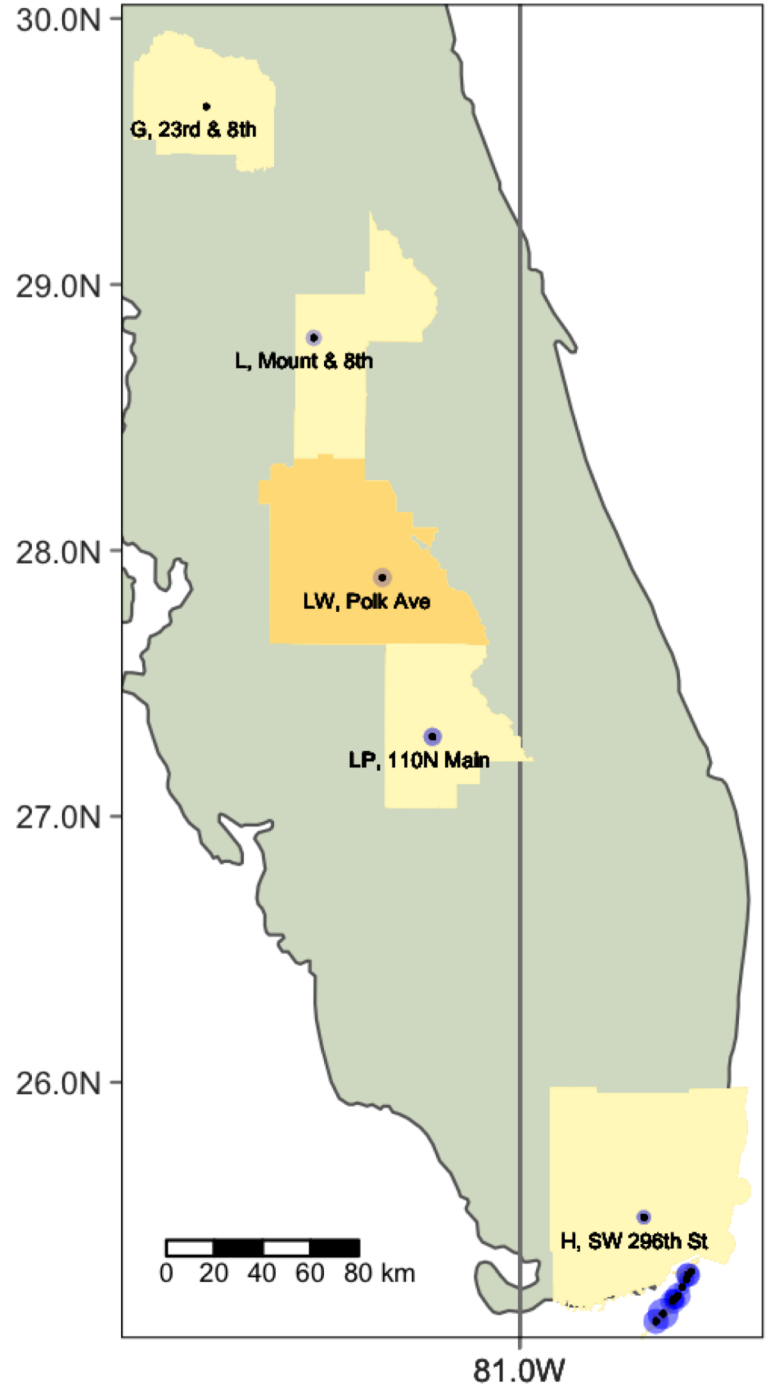
Average Speed Across Latitude



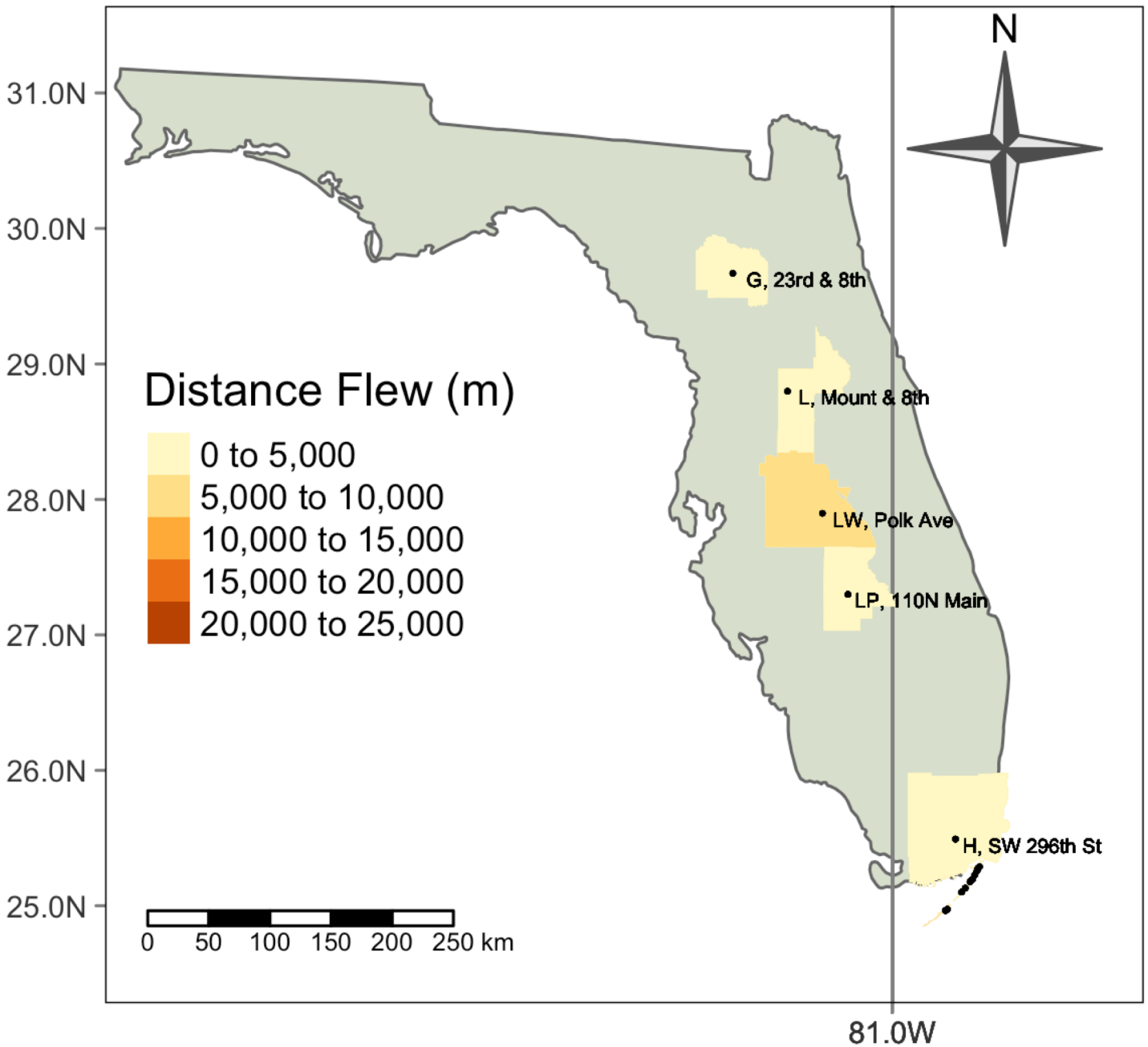


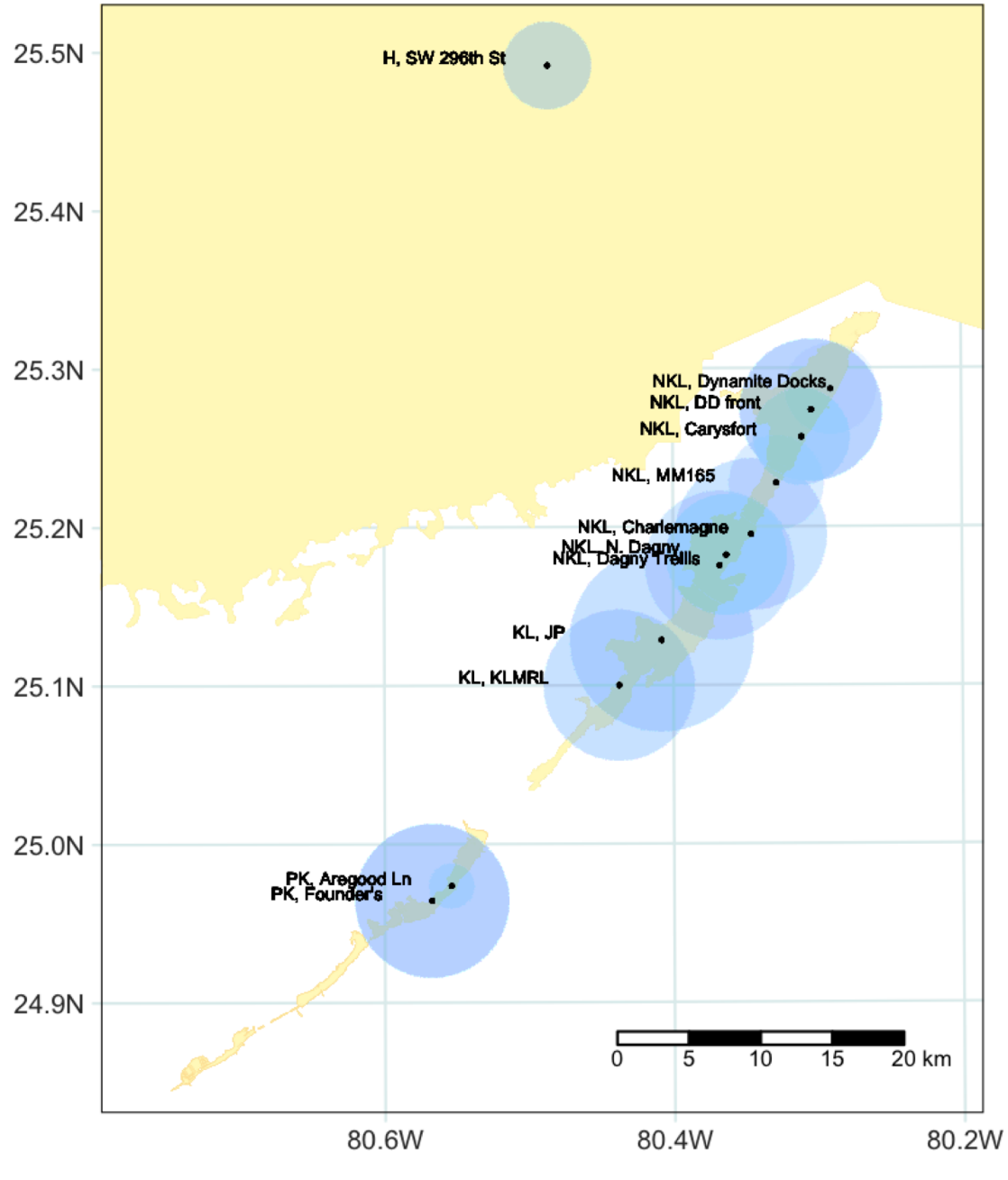
Distance Flew Across Latitude



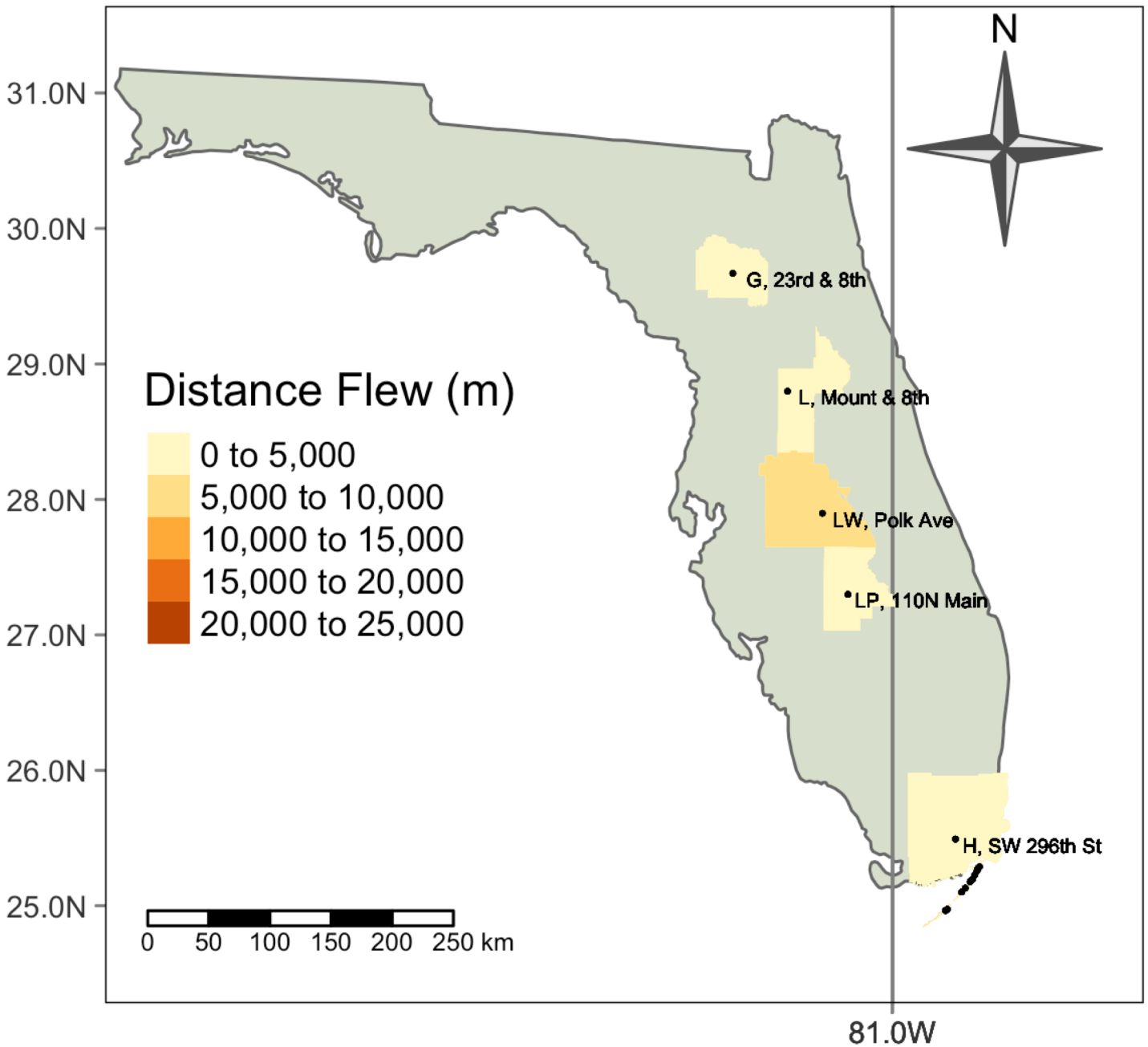


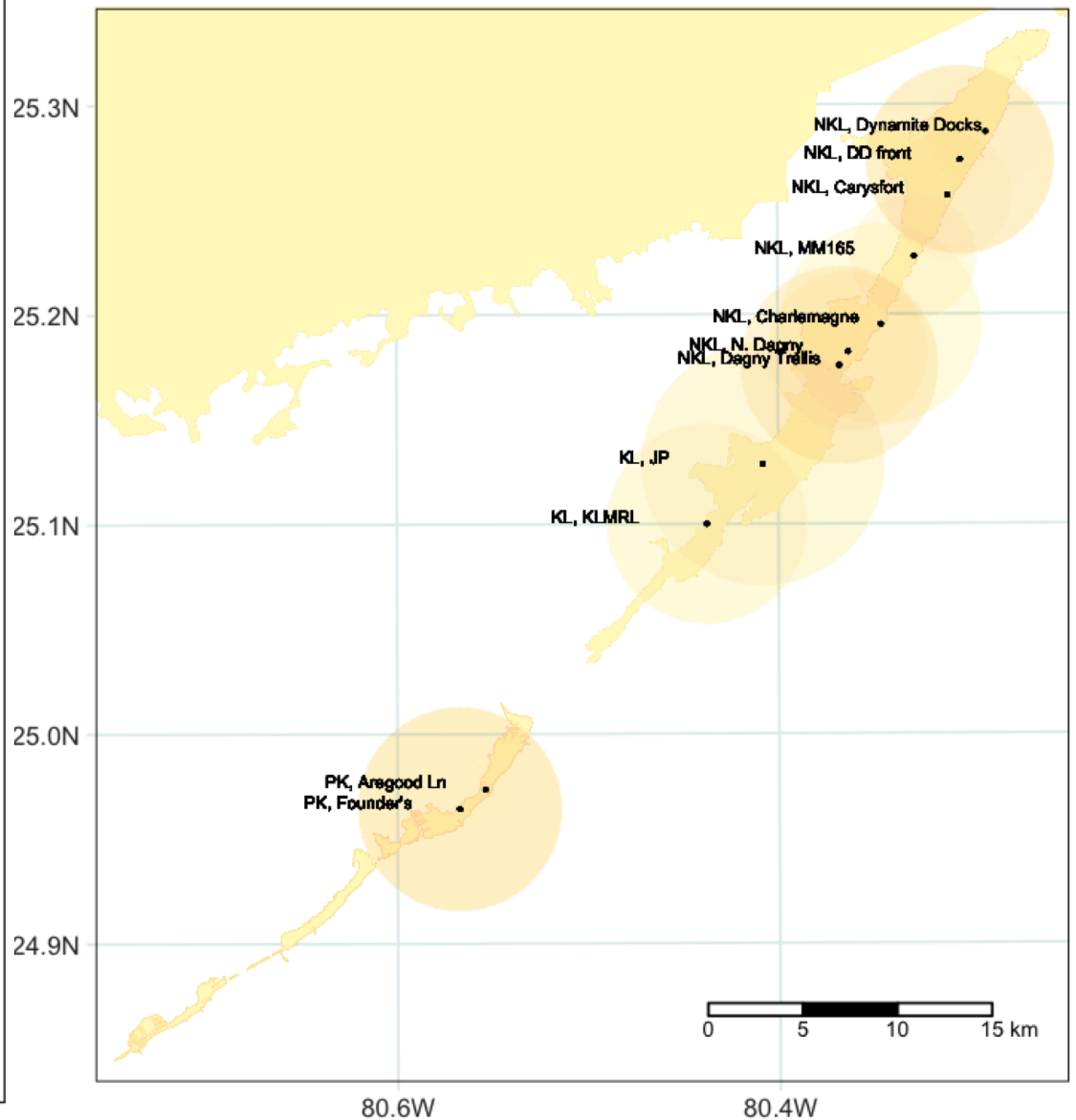
Distance Flew Across Latitude



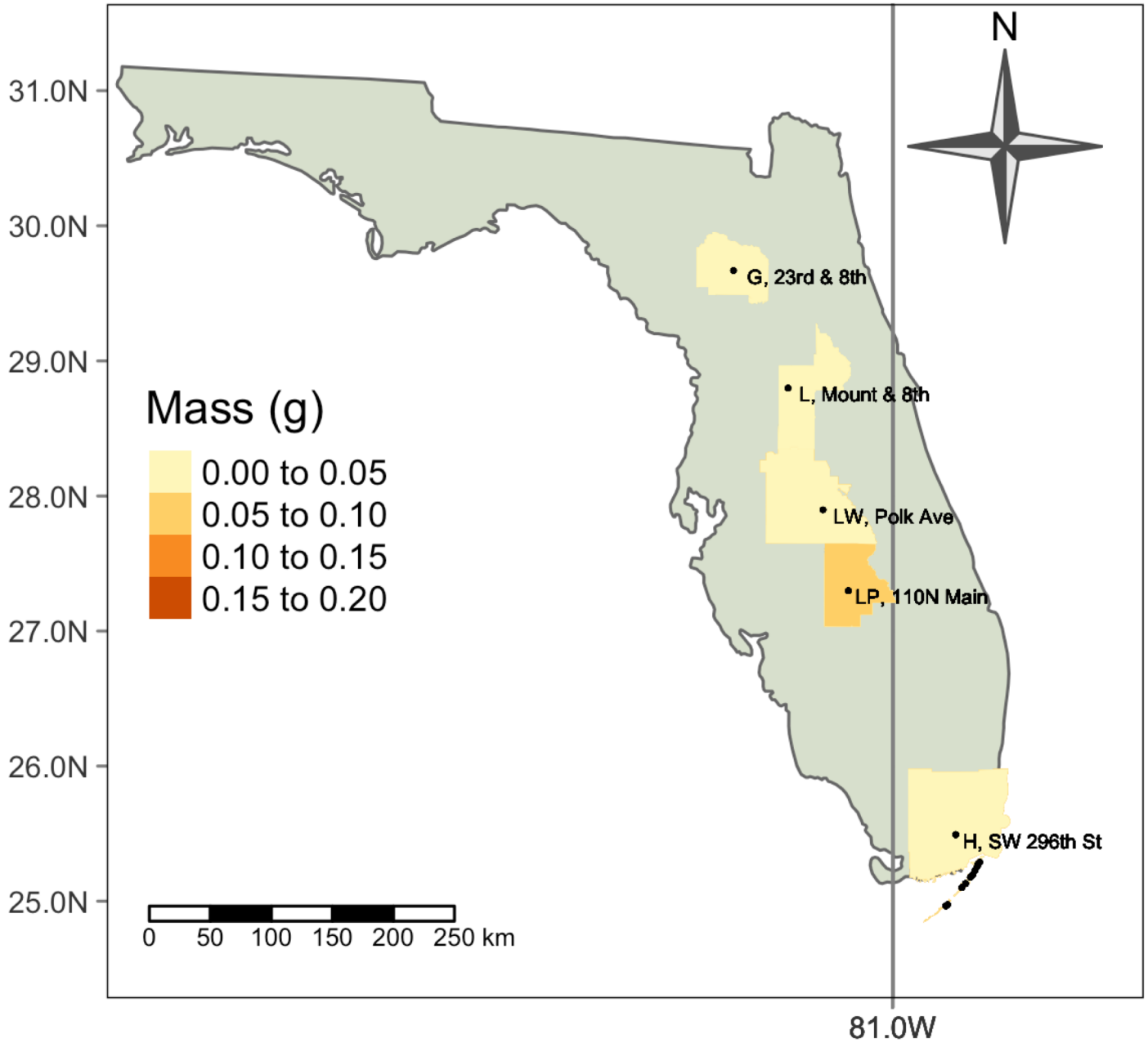


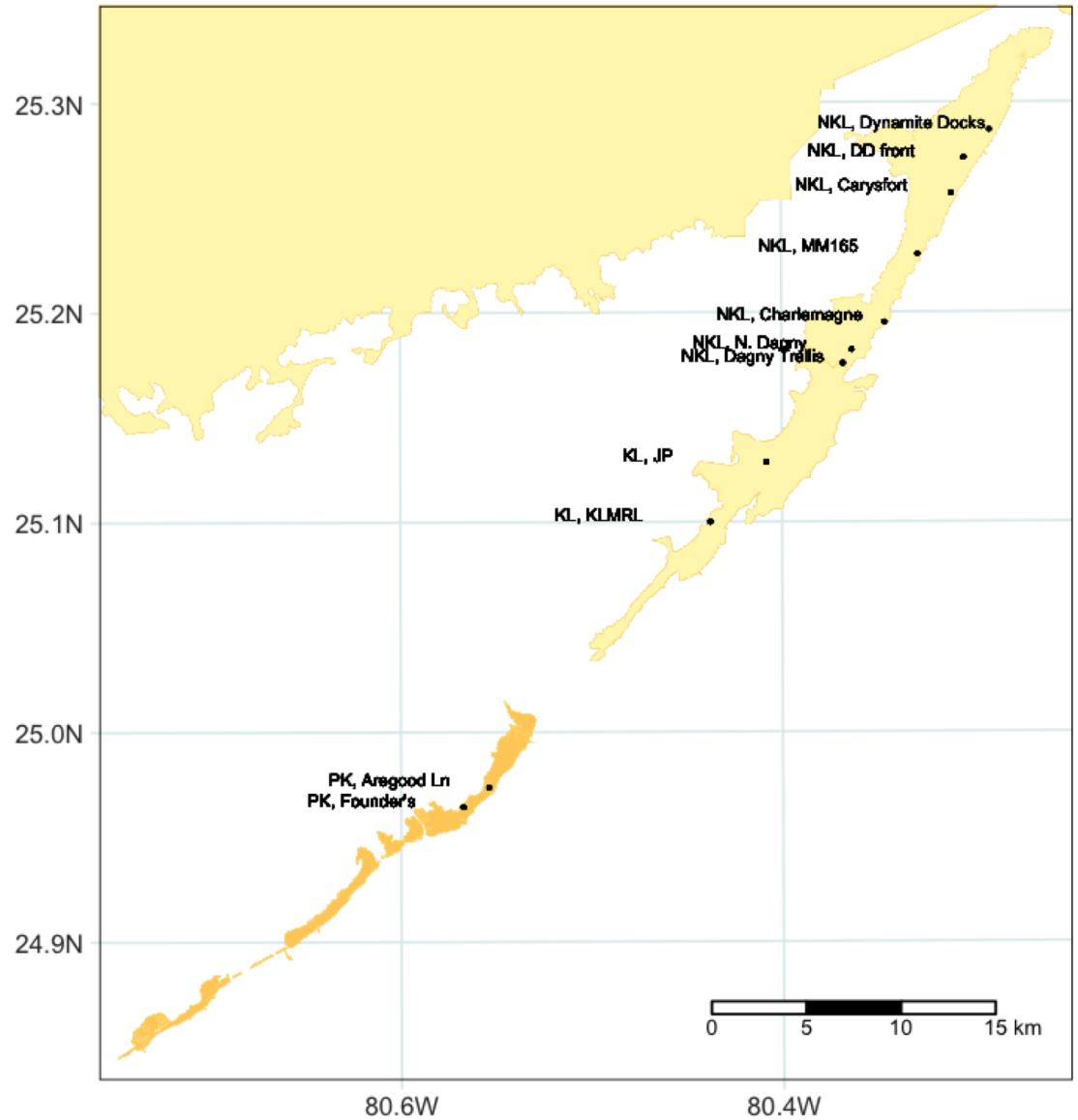
Distance Flew Across Latitude



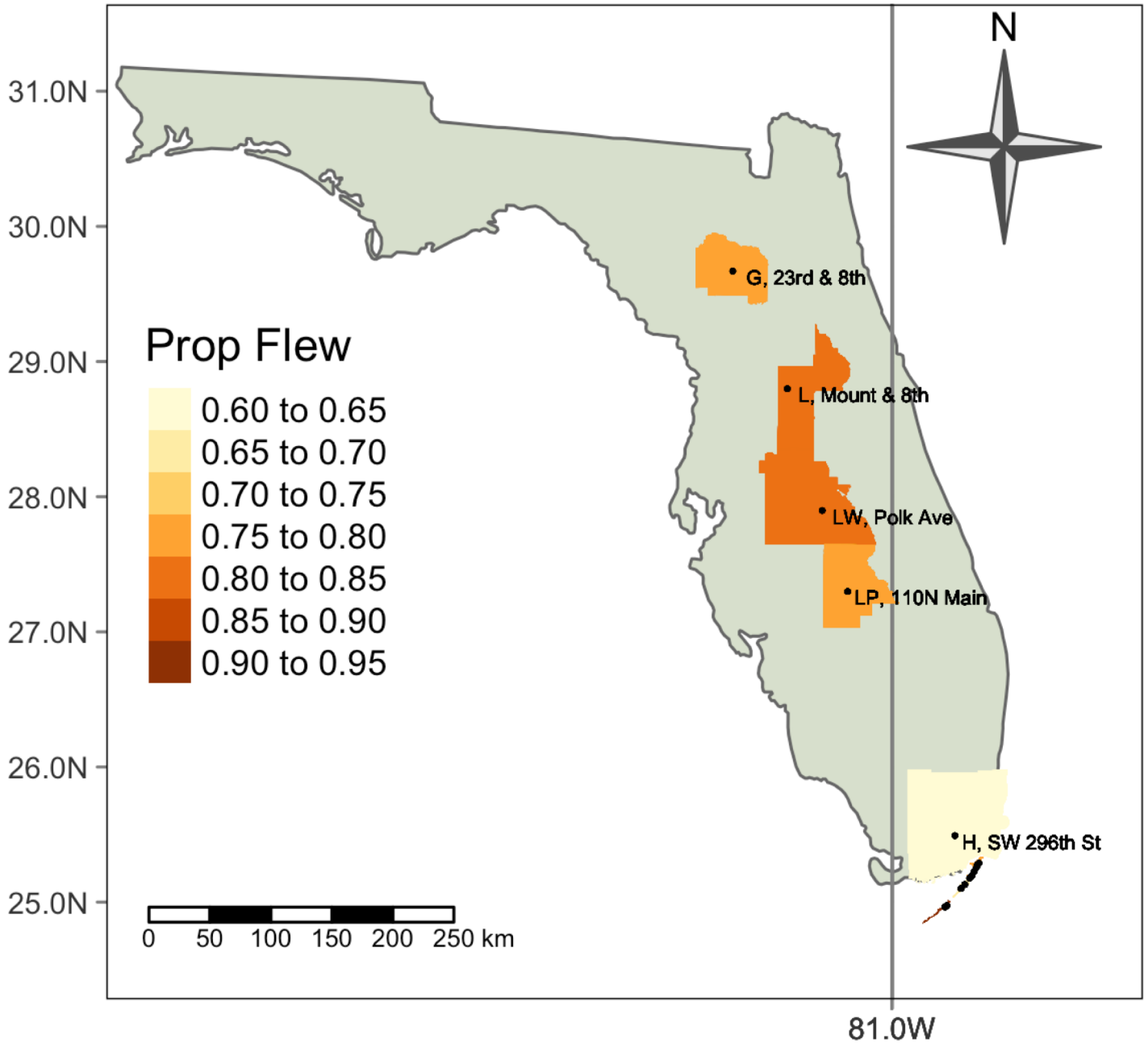


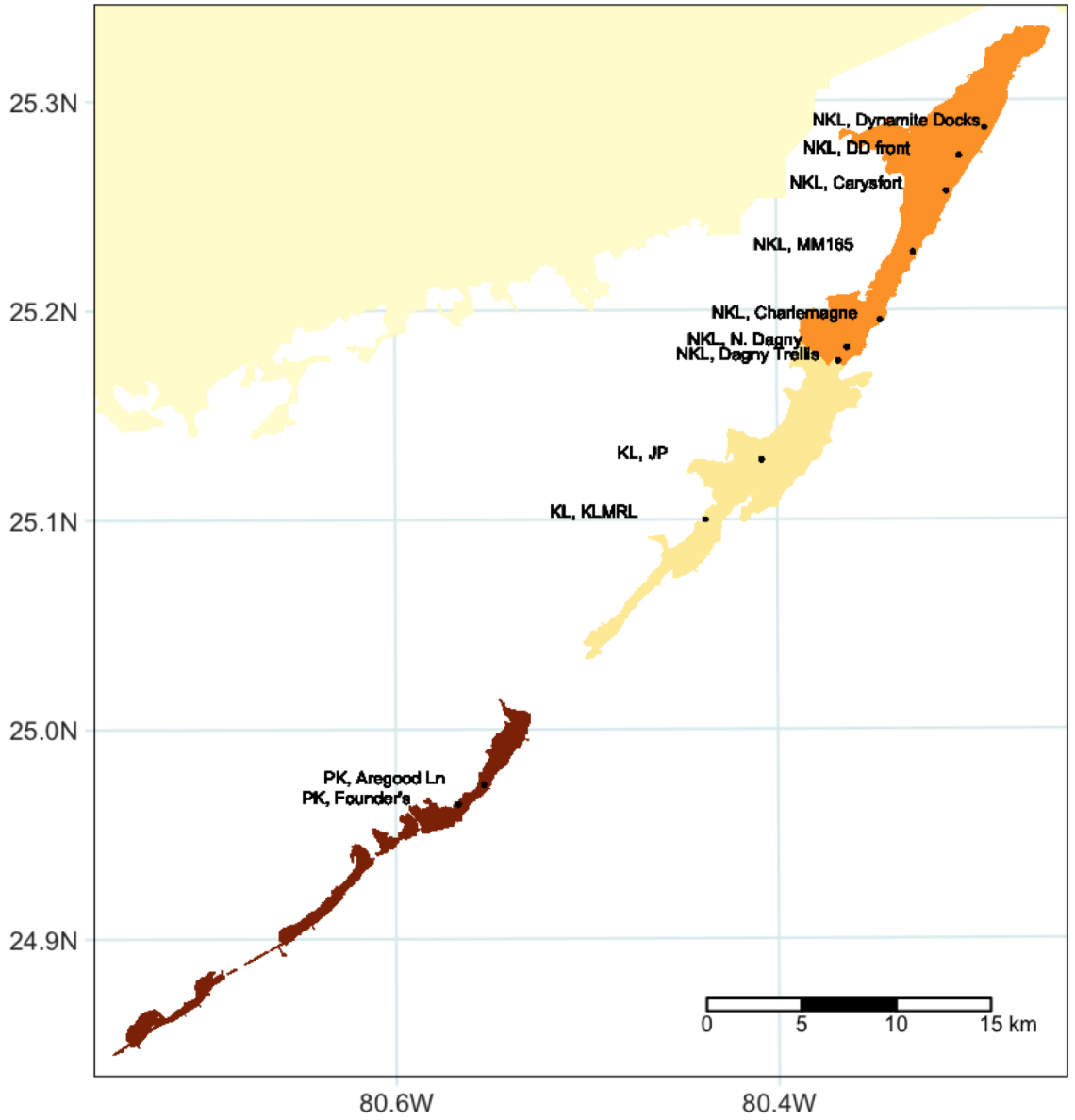
Mass Across Latitude



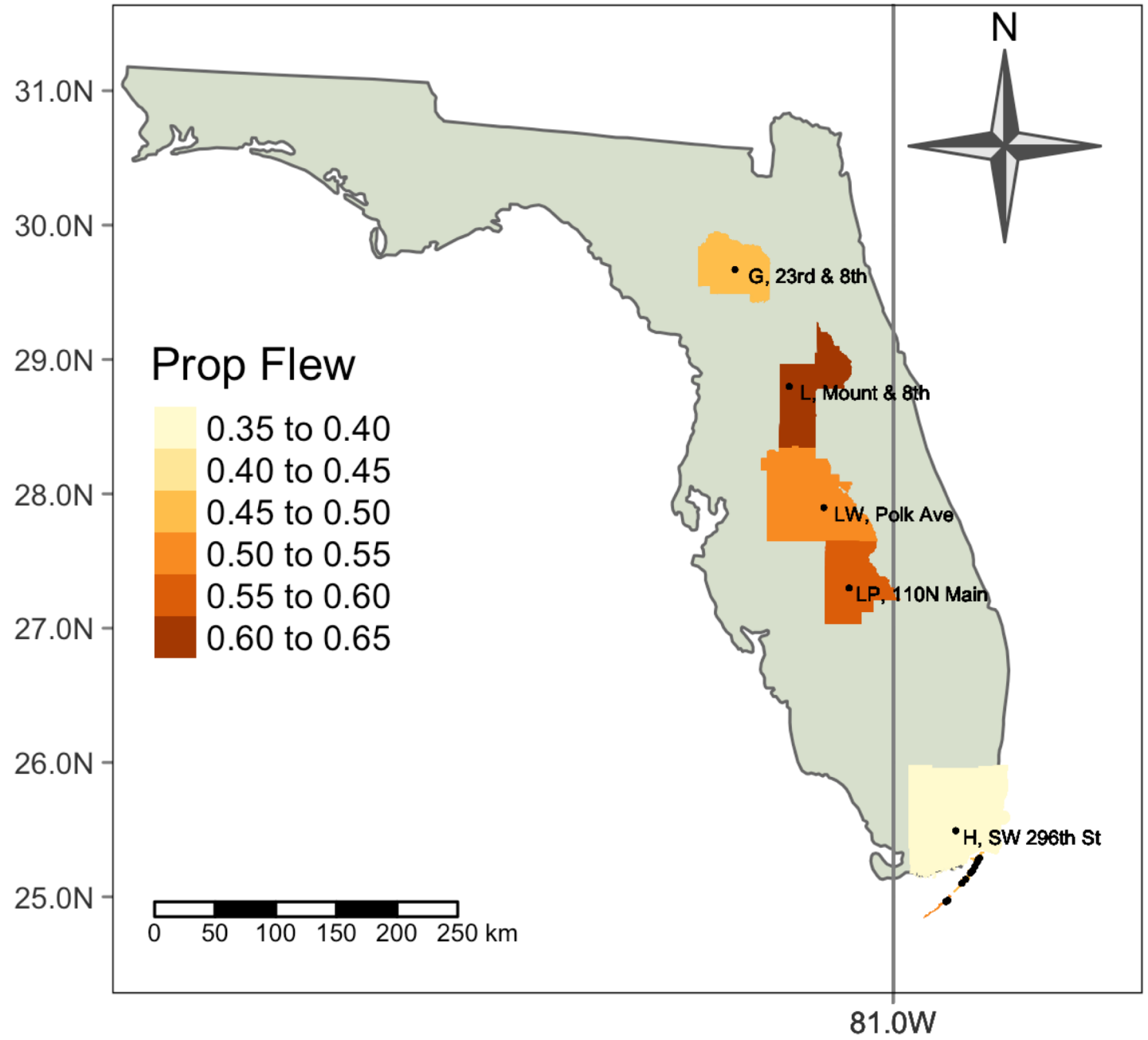


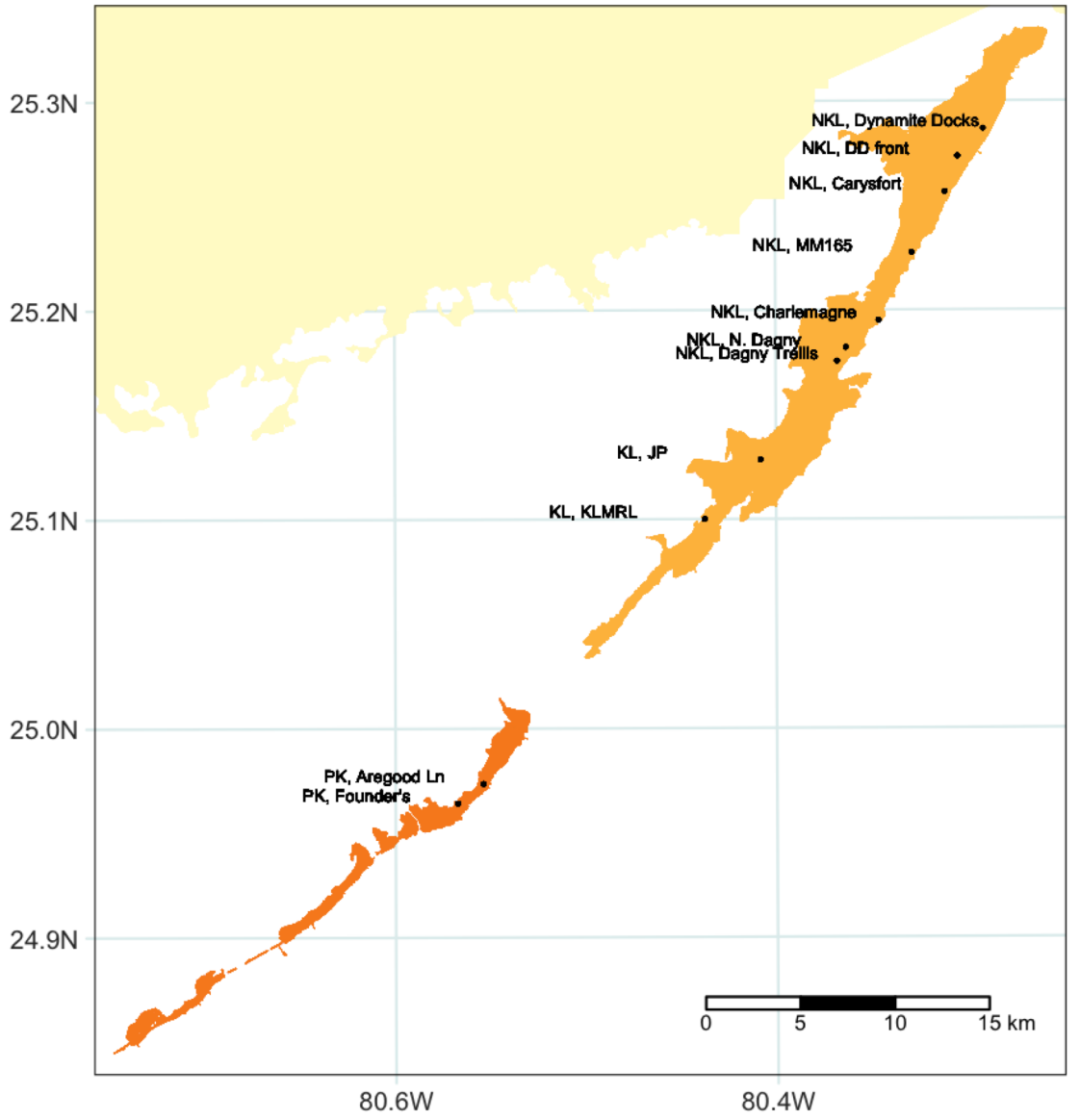
Proportion Flew Across Latitude (Tested Bugs Only)





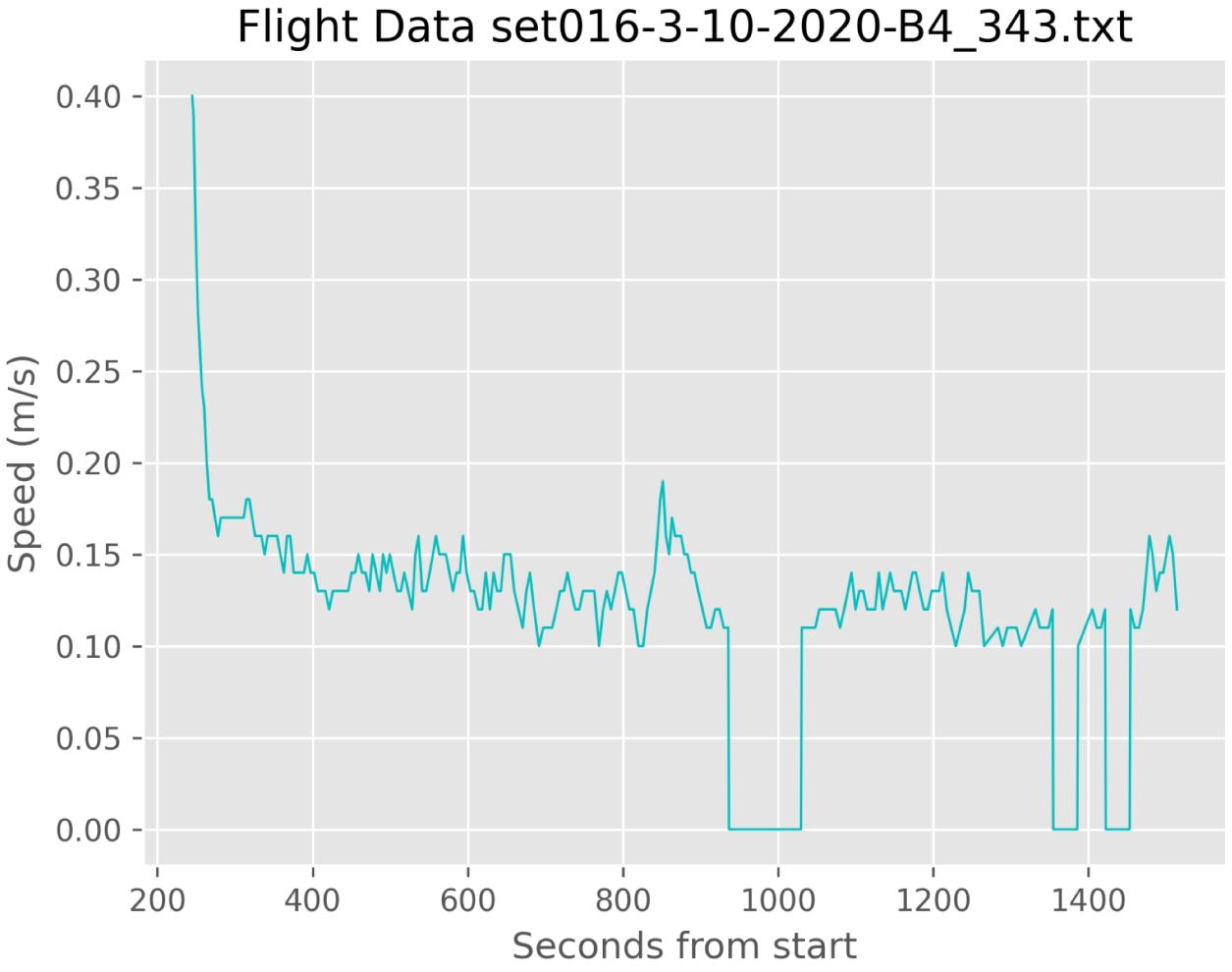
Proportion Flew Across Latitude (All Bugs – Tested Long Wings + Not Tested Short-Wings)

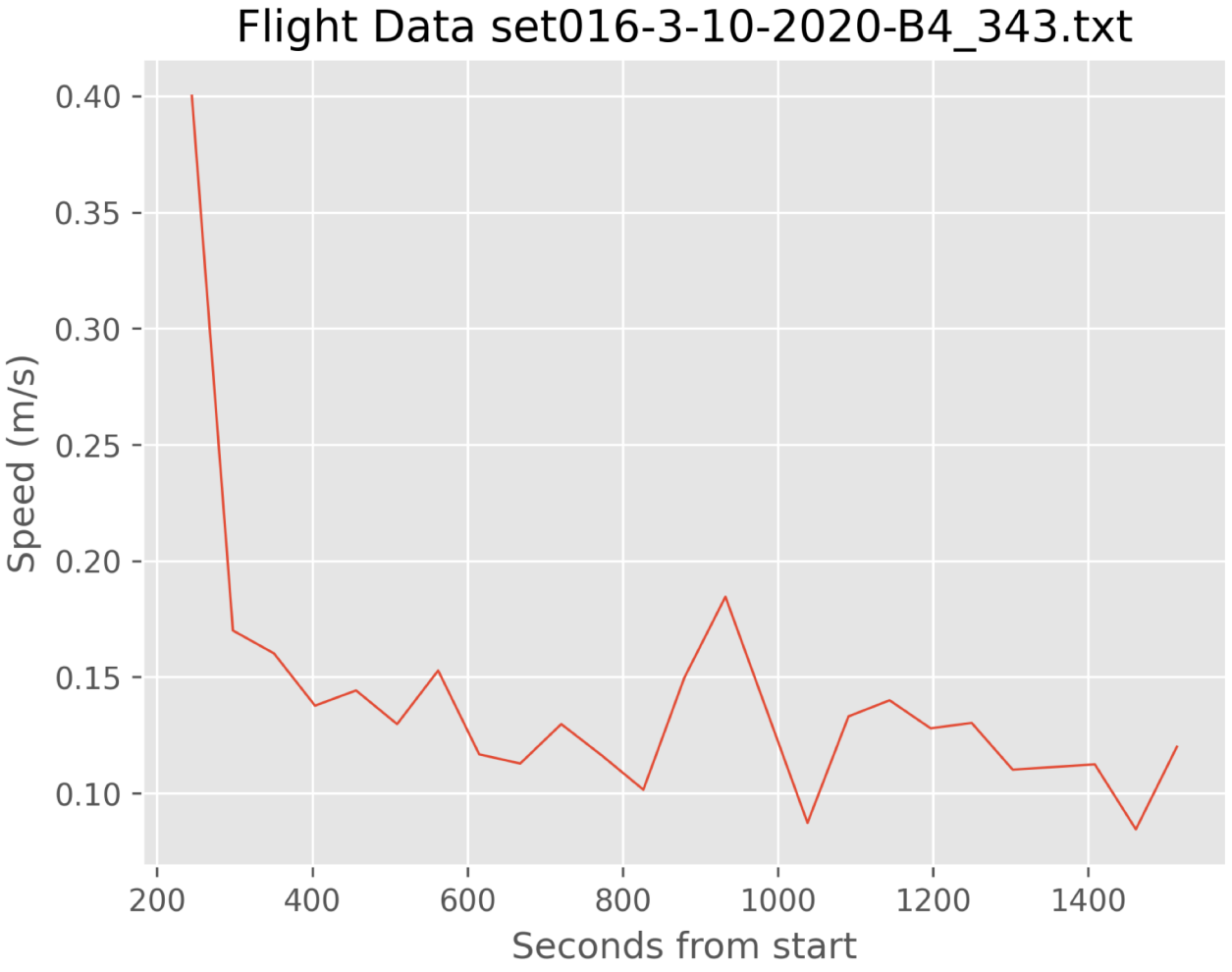




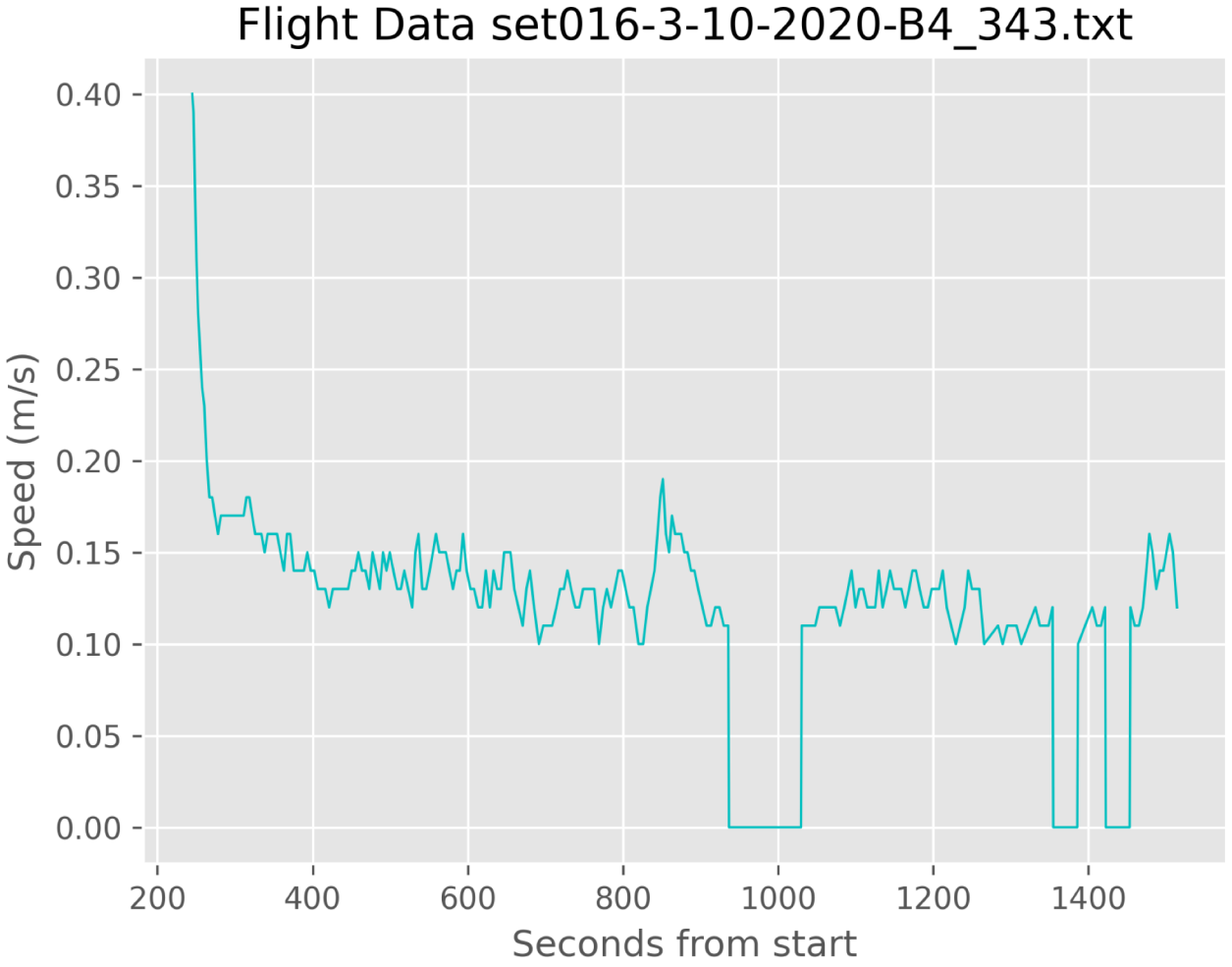
Flight Trajectories

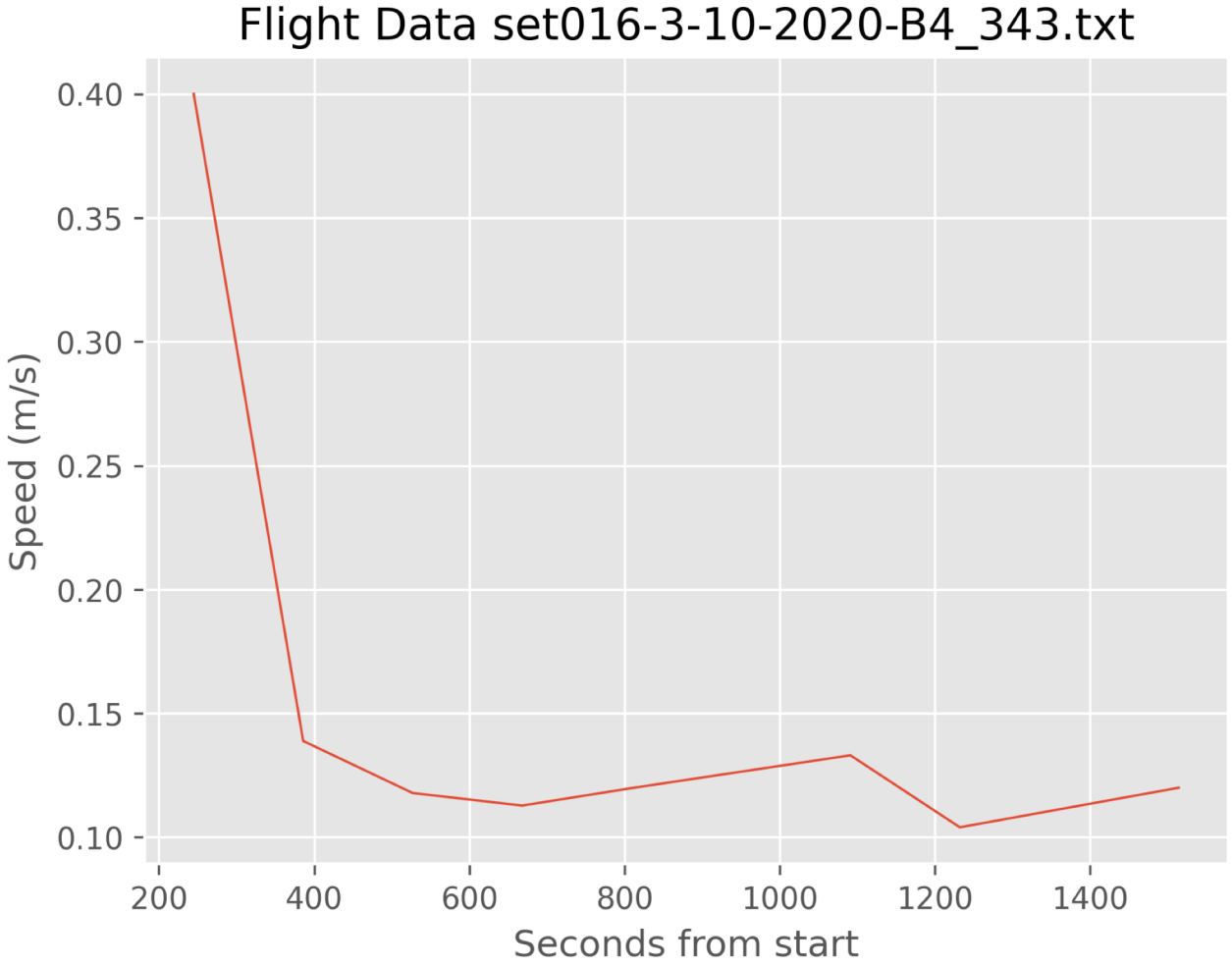
Continuous flyers only.
No speeds > 0.8 m/s
Spline smoothed with **25 points** plotted between initial and final time.
Removed negative spline speeds.



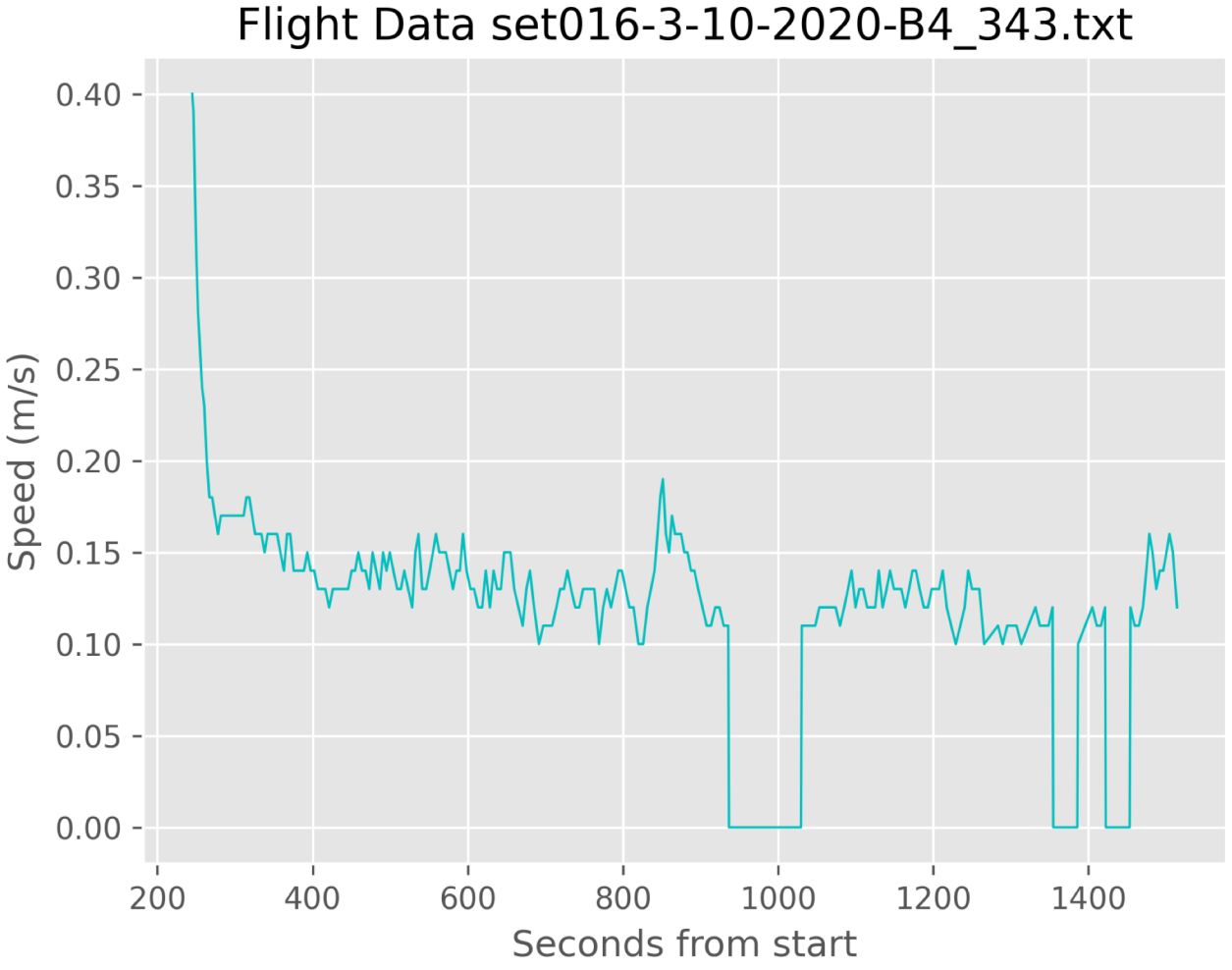


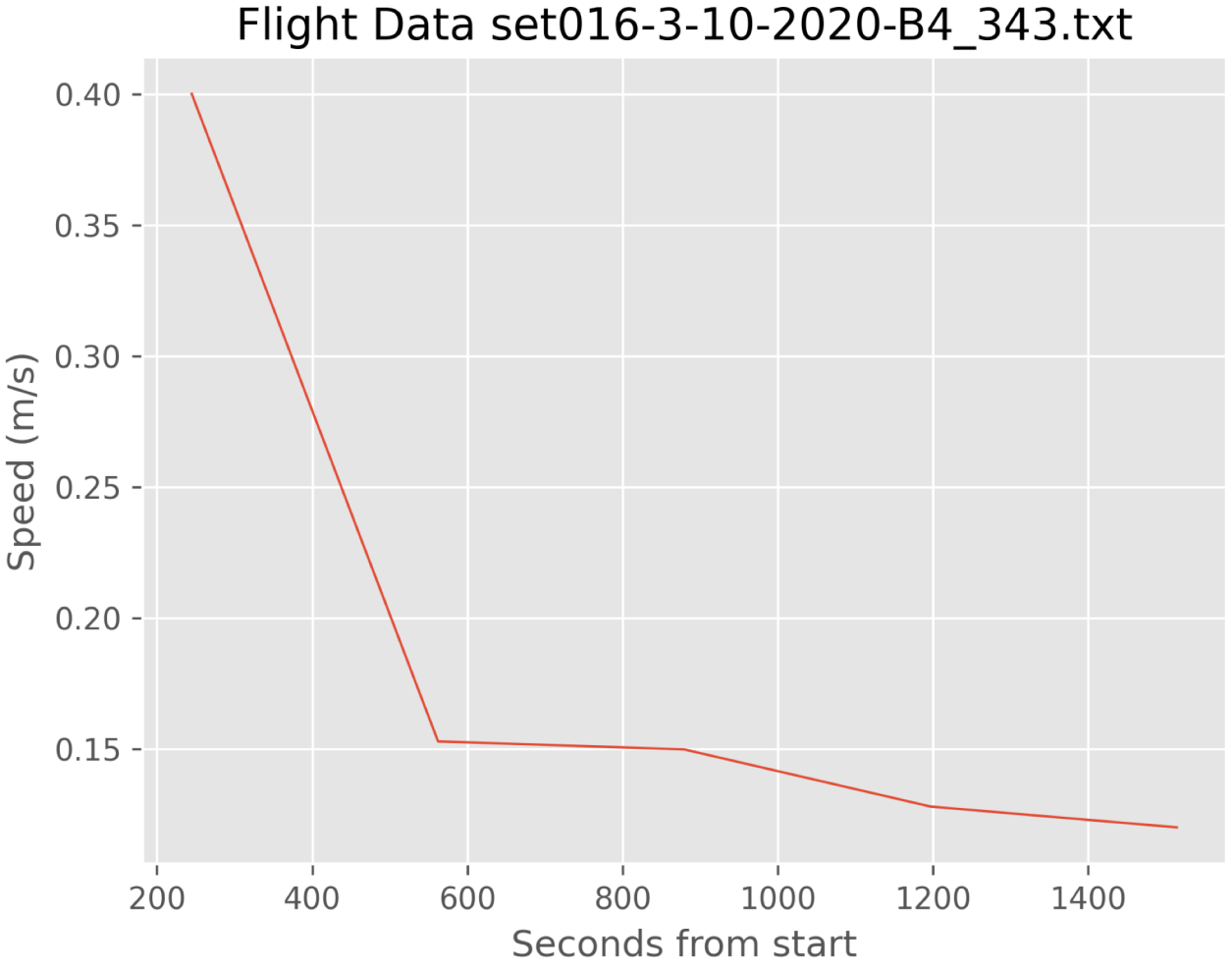
Continuous flyers only.
No speeds > 0.8 m/s
Spline smoothed with **10 points** plotted between initial and final time.
Removed negative spline speeds.

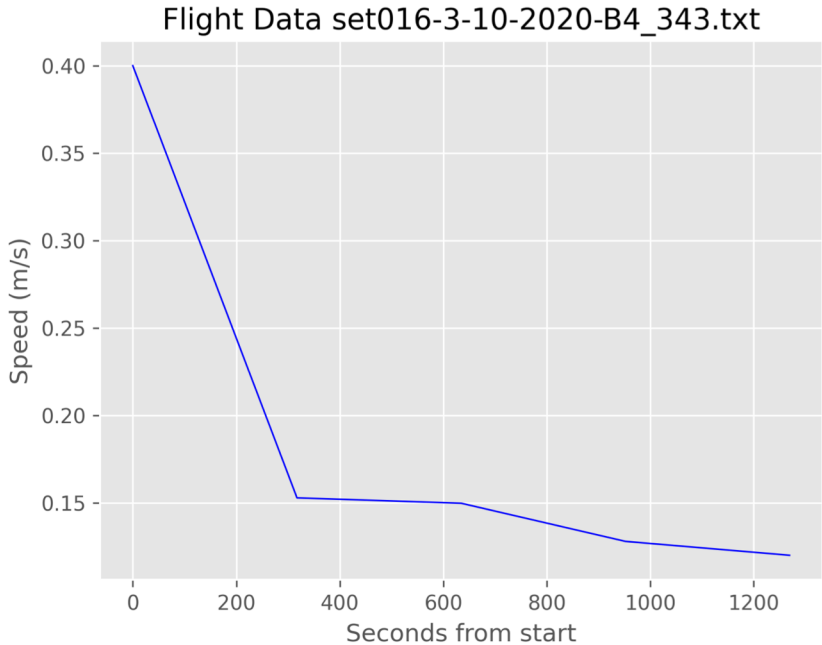


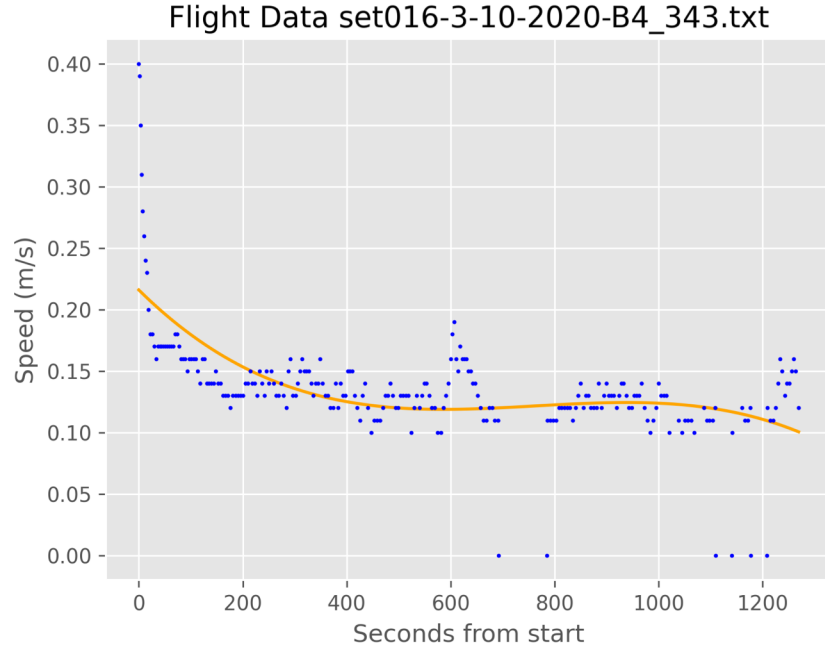


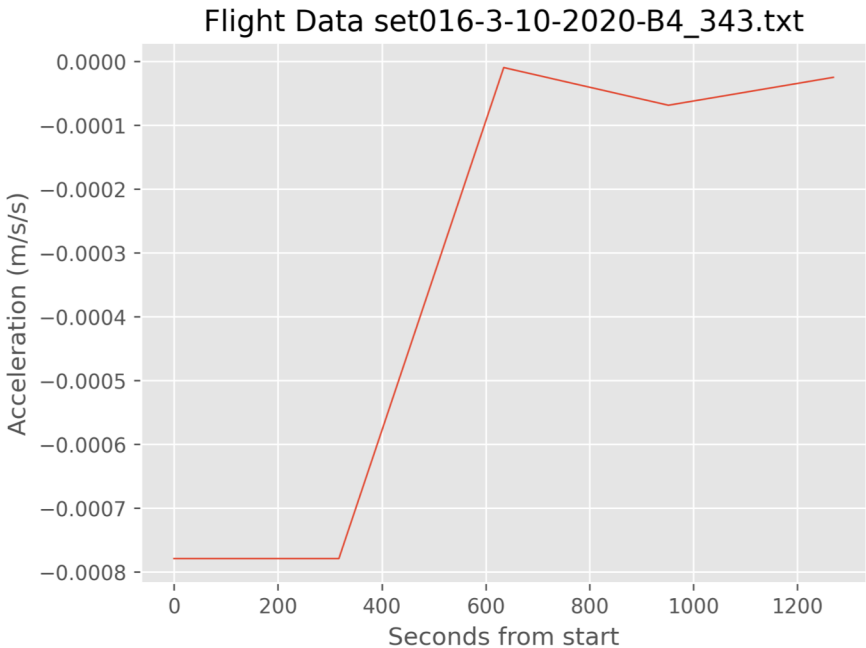
Continuous flyers only.
No speeds > 0.8 m/s
Spline smoothed with **5 points** plotted between initial and final time.
Removed negative spline speeds.



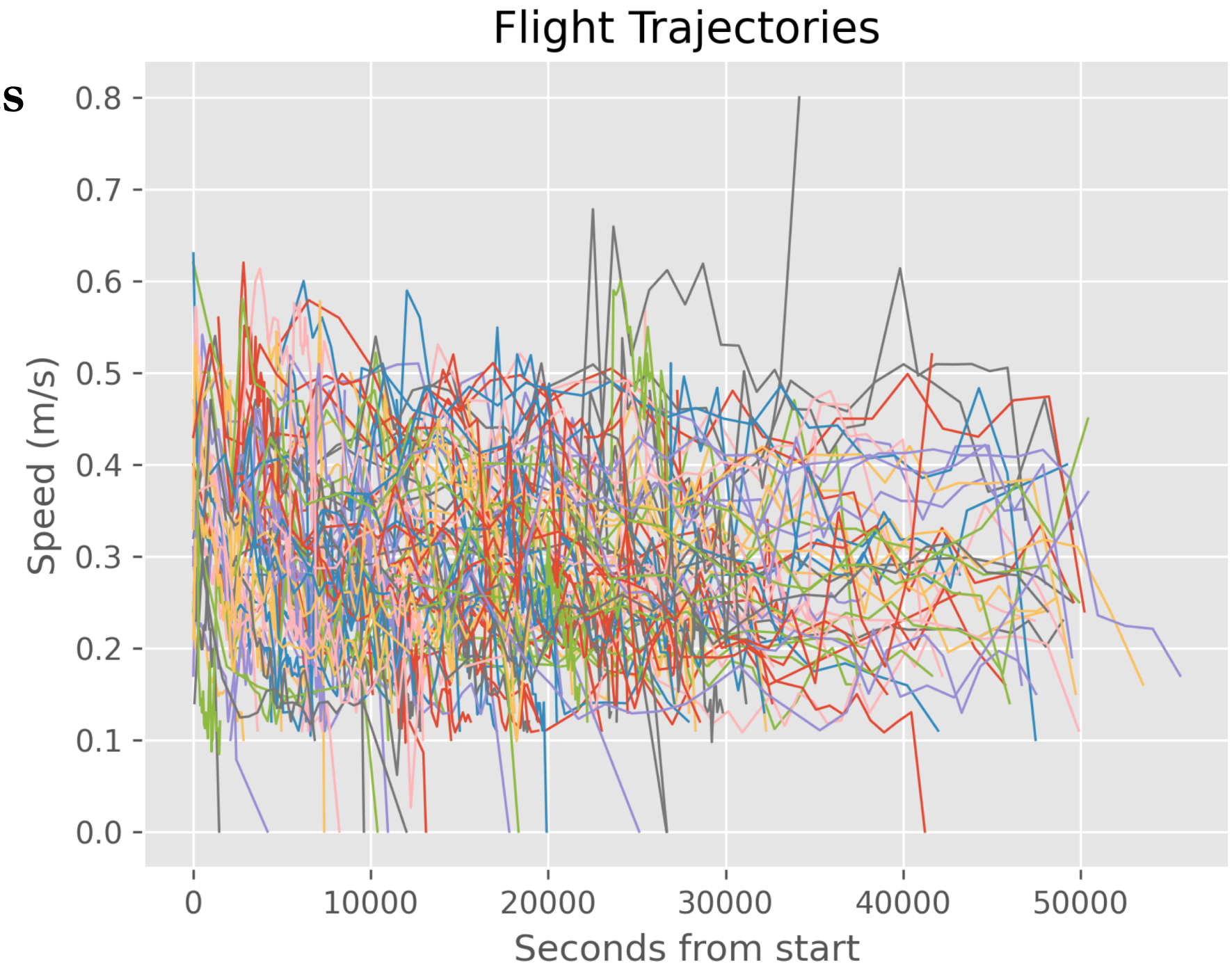



Flight Data set016-3-10-2020-B4_343.txt
Speed (m/s)
0.40
0.35
0.30
0.25
0.20
0.15
0
200
400
600
800
1000
1200
Seconds from start

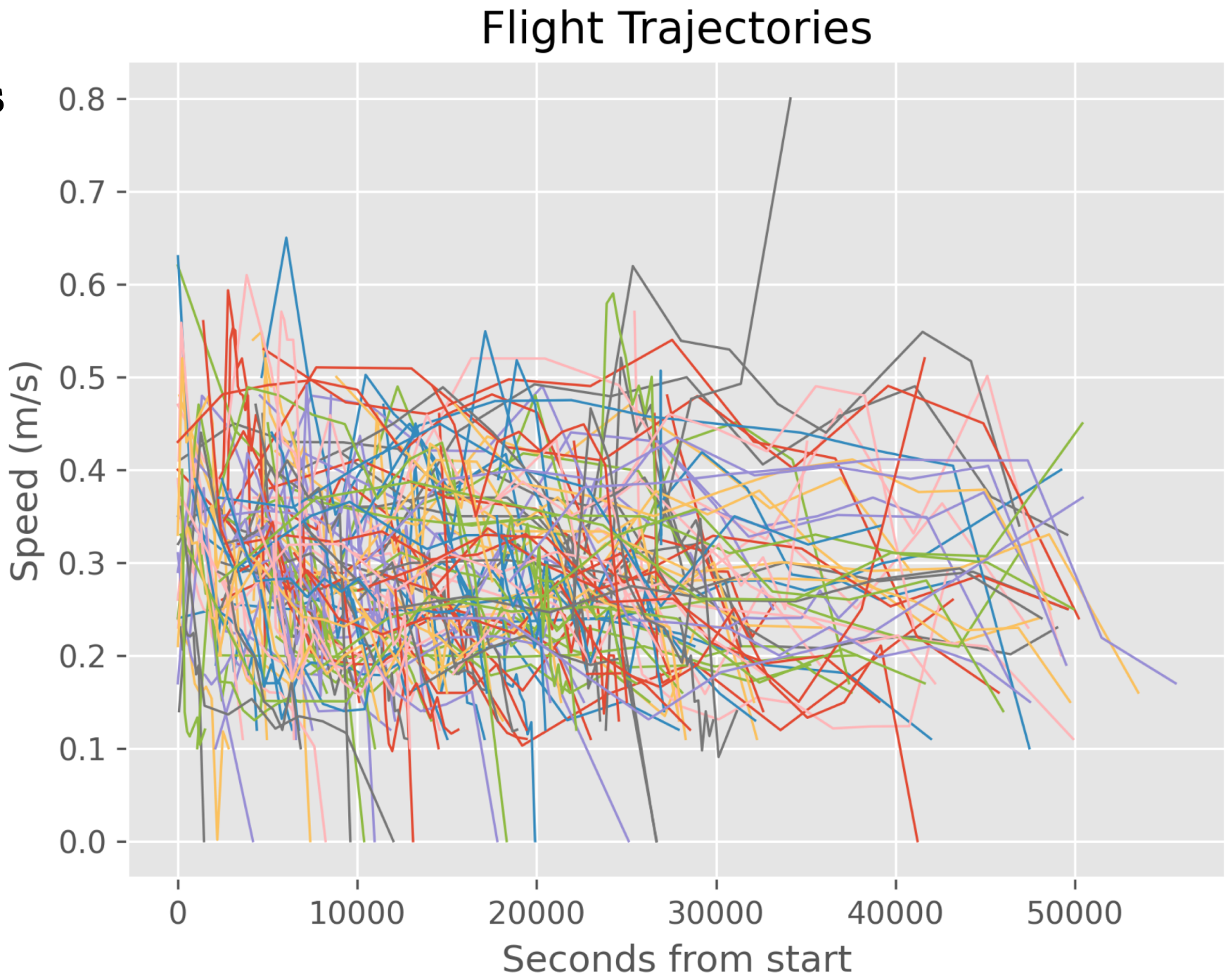

Flight Data set016-3-10-2020-B4_343.txt
Speed (m/s)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
200
400
600
800
1000
1200
Seconds from start


Flight Data set016-3-10-2020-B4_343.txt
Acceleration (m/s/s)
0.0000
−0.0001
−0.0002
−0.0003
−0.0004
−0.0005
−0.0006
−0.0007
−0.0008
0
200
400
600
800
1000
1200
Seconds from start

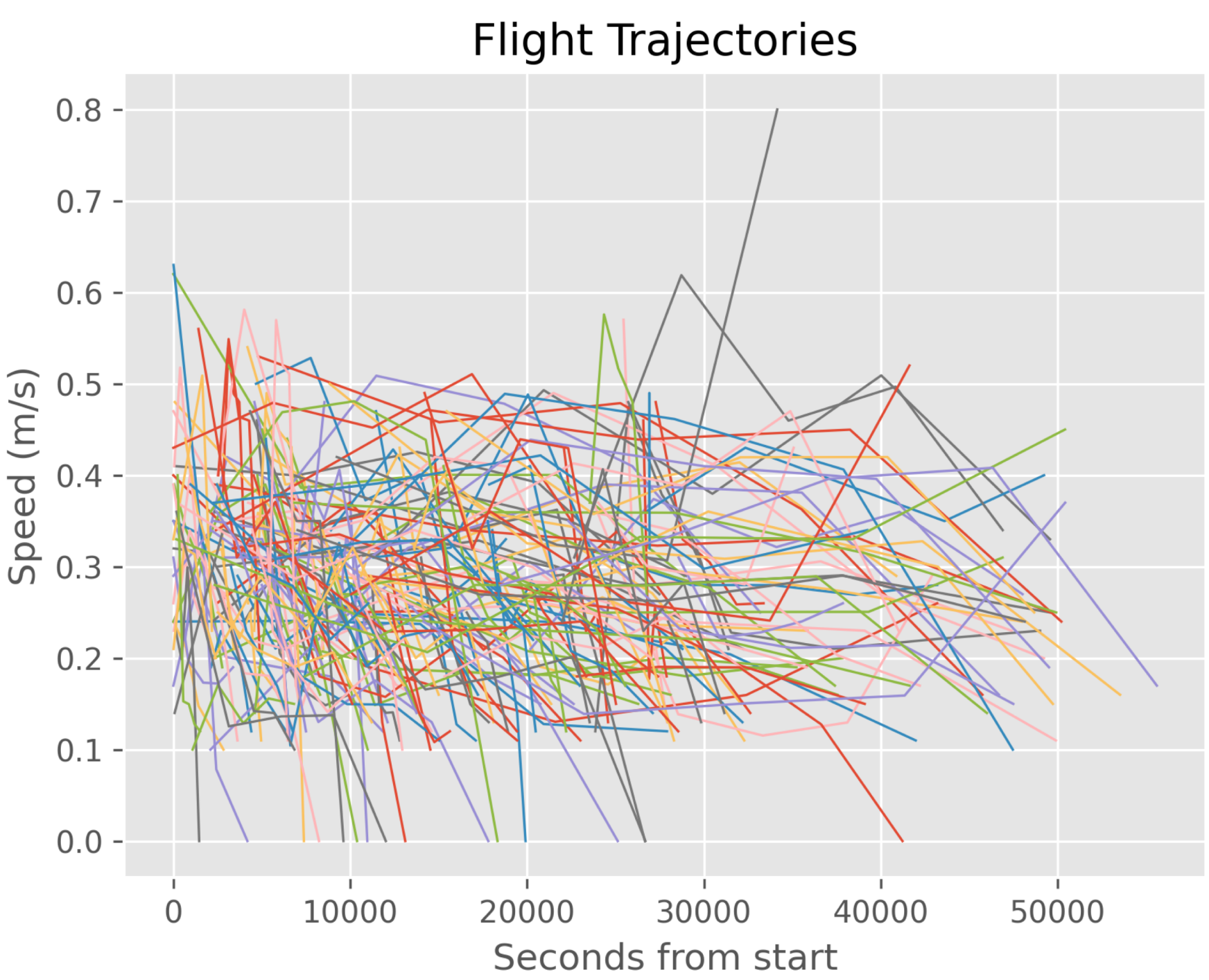
25 points


Flight Trajectories
Speed (m/s)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
10000
20000
30000
40000
50000
Seconds from start

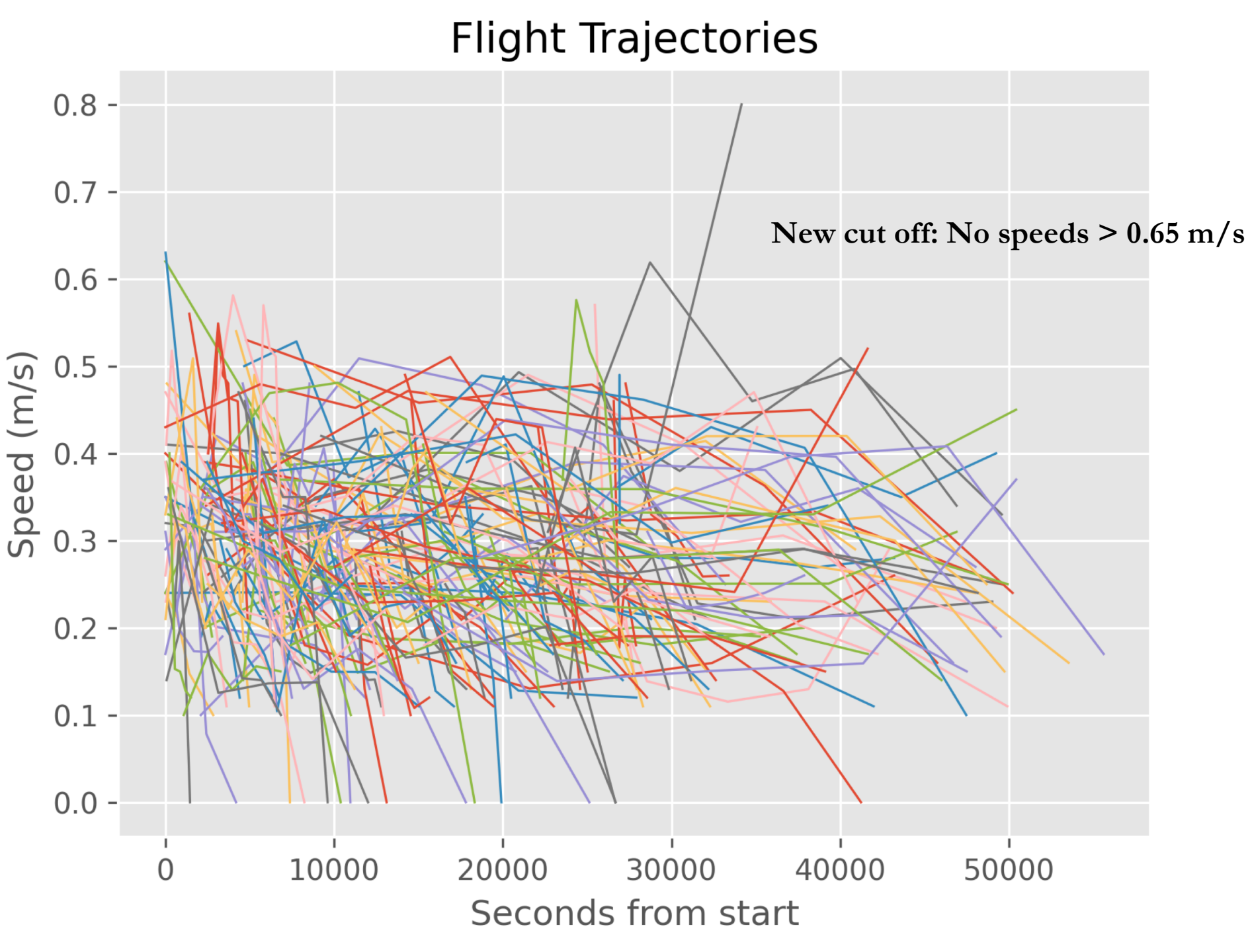
10 points

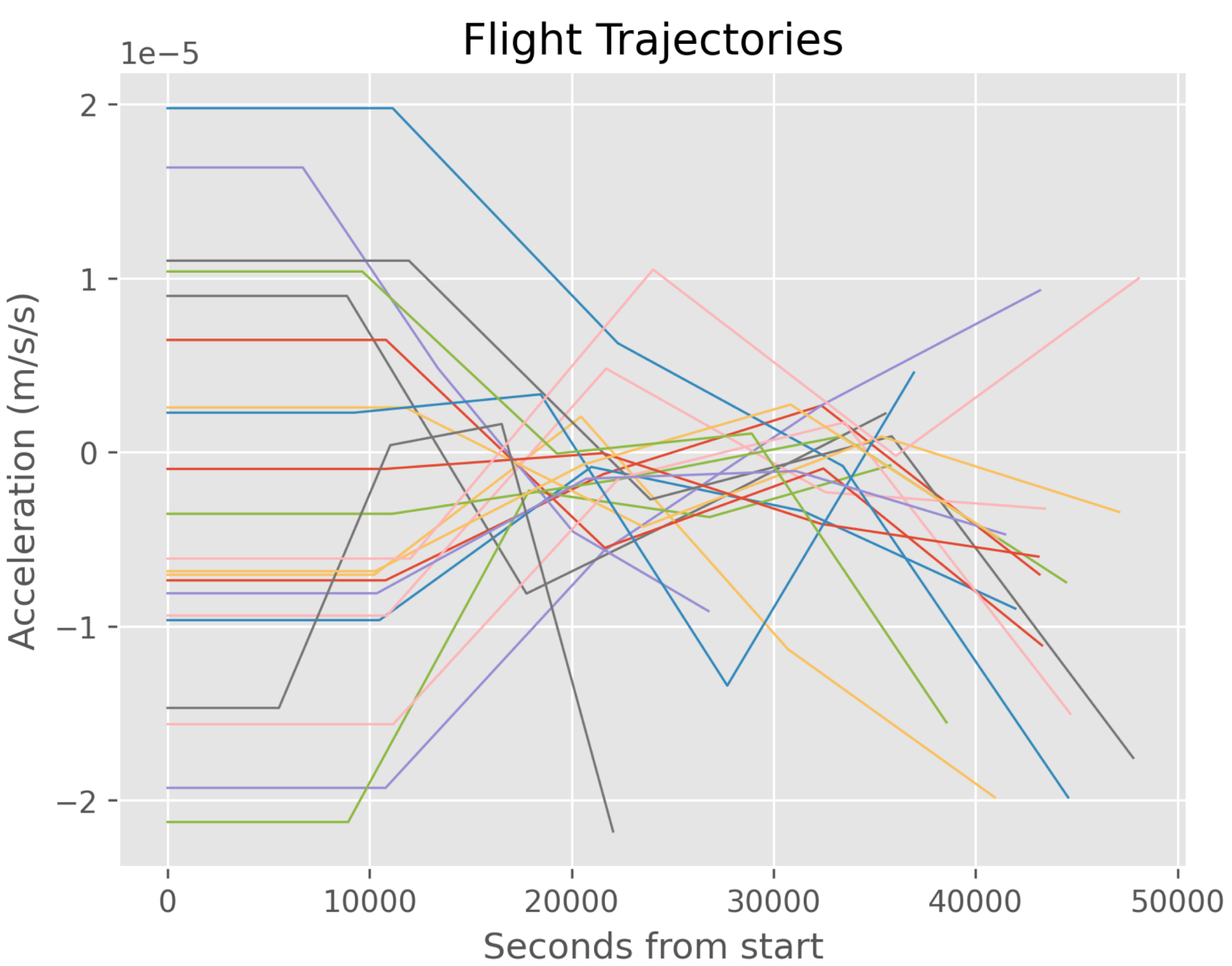

Flight Trajectories
Speed (m/s)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
10000
20000
30000
40000
50000
Seconds from start

5 points


Flight Trajectories
Speed (m/s)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
10000
20000
30000
40000
50000
Seconds from start

5 points

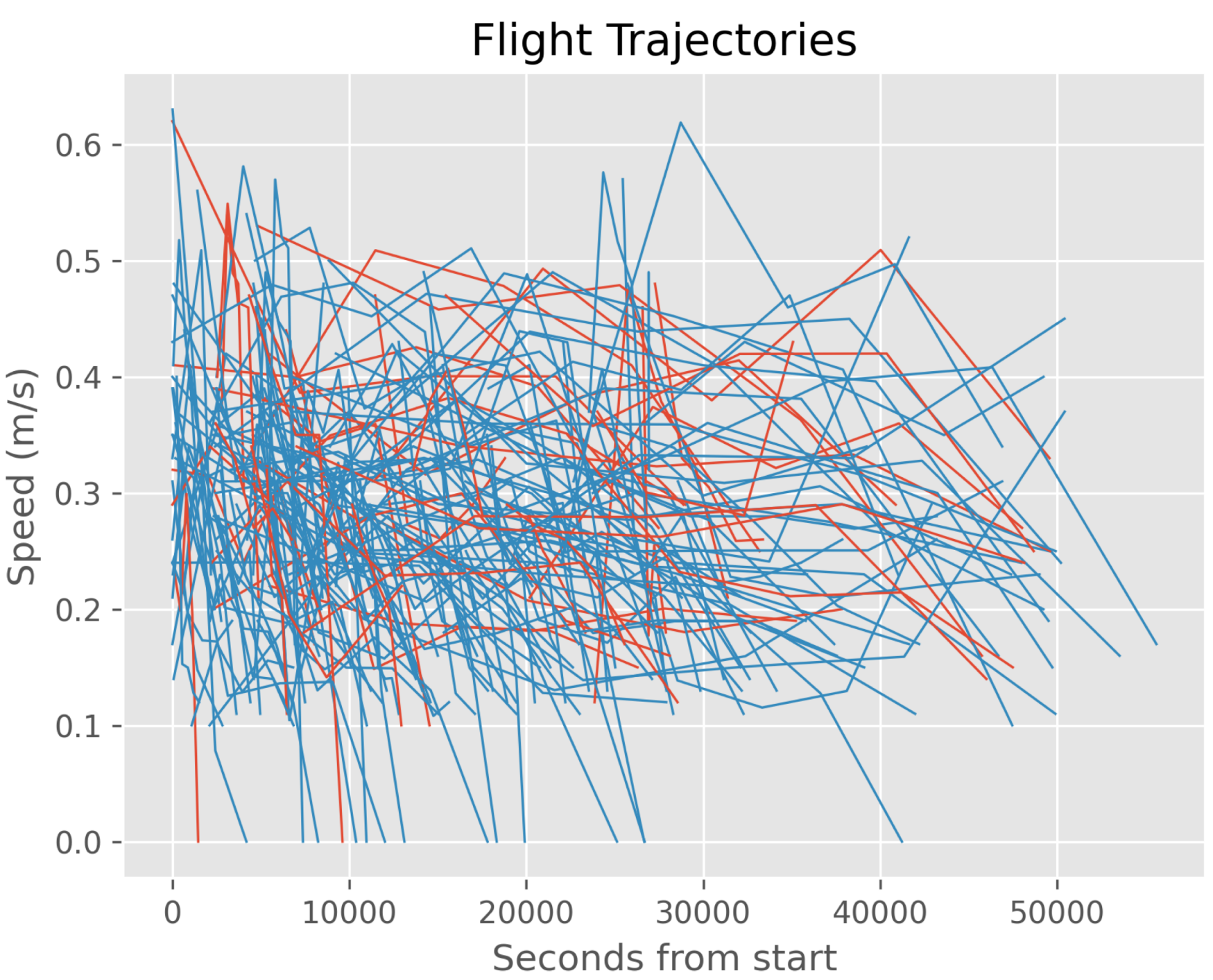

Flight Trajectories
Speed (m/s)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
10000
20000
30000
40000
50000
Seconds from start
New cut off: No speeds > 0.65 m/s


Flight Trajectories
1e−5
2
1
0
−1
−2
Acceleration (m/s/s)
0
10000
20000
30000
40000
50000
Seconds from start

5 points | Sex

Female

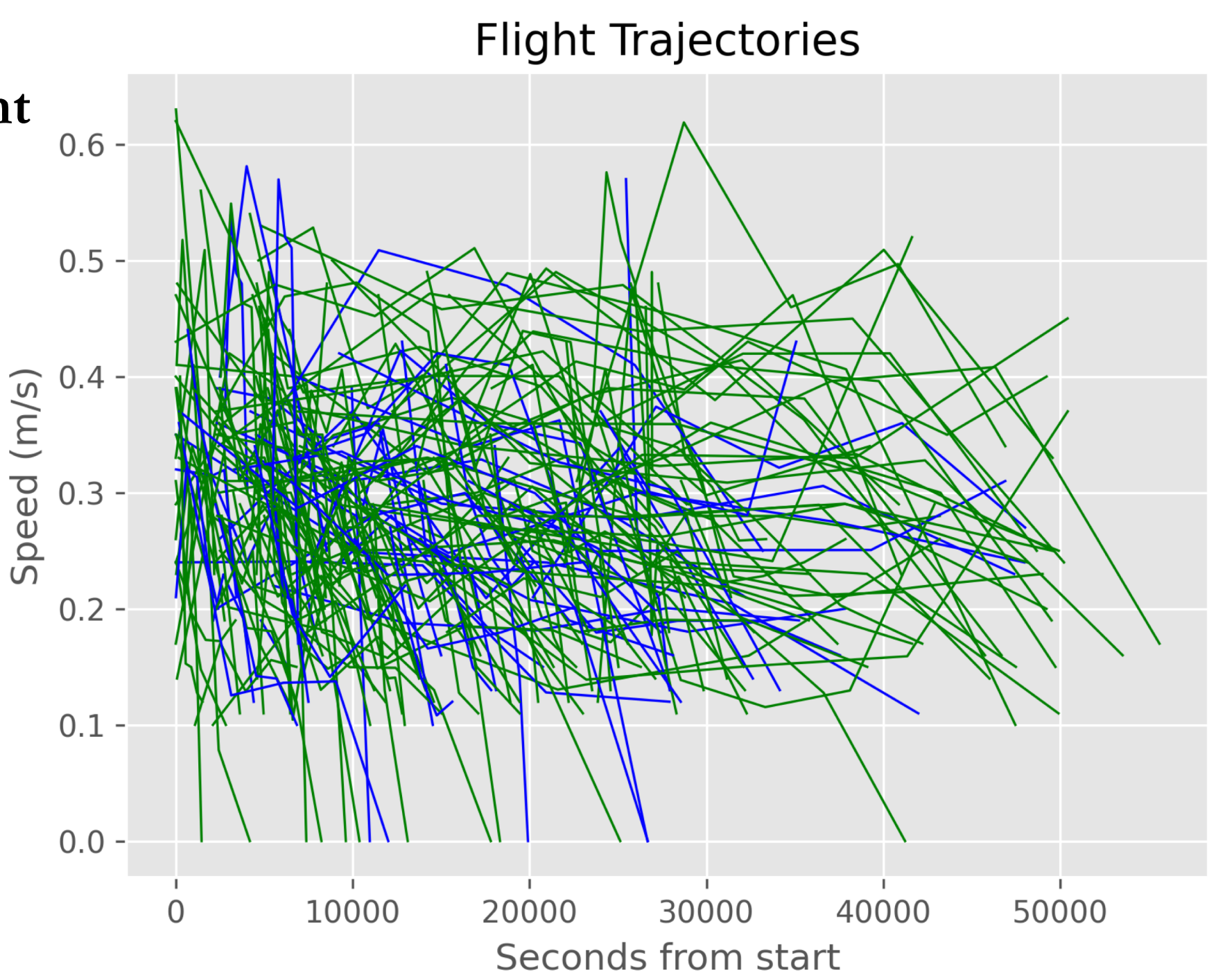
Male



5 points | Host Plant

C. corindum

K. elegans



5 points | Population

Lake Wales

Lake Placid

Plantation Key

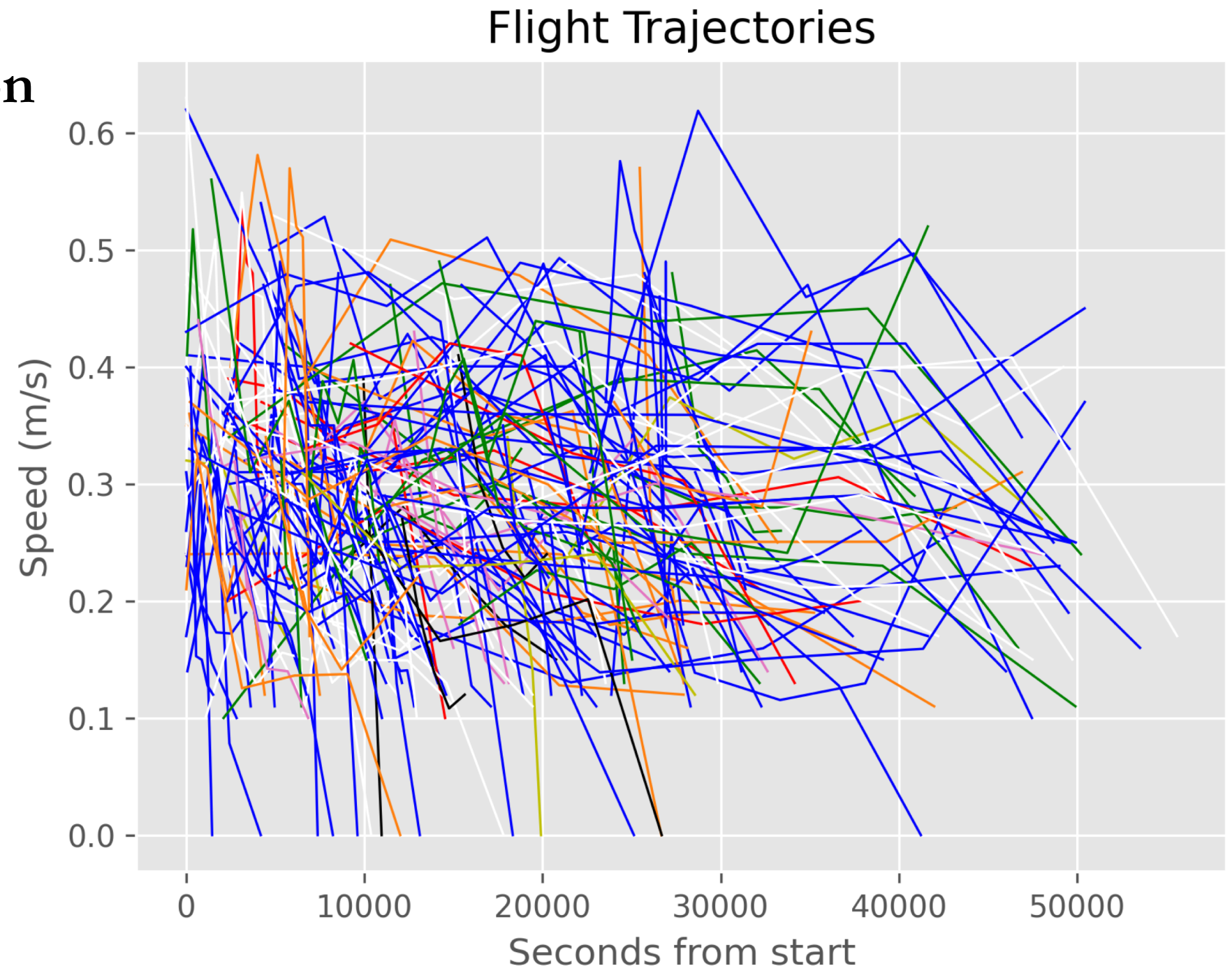
North Key Largo

Key Largo

Homestead

Leesburg

Gainesville

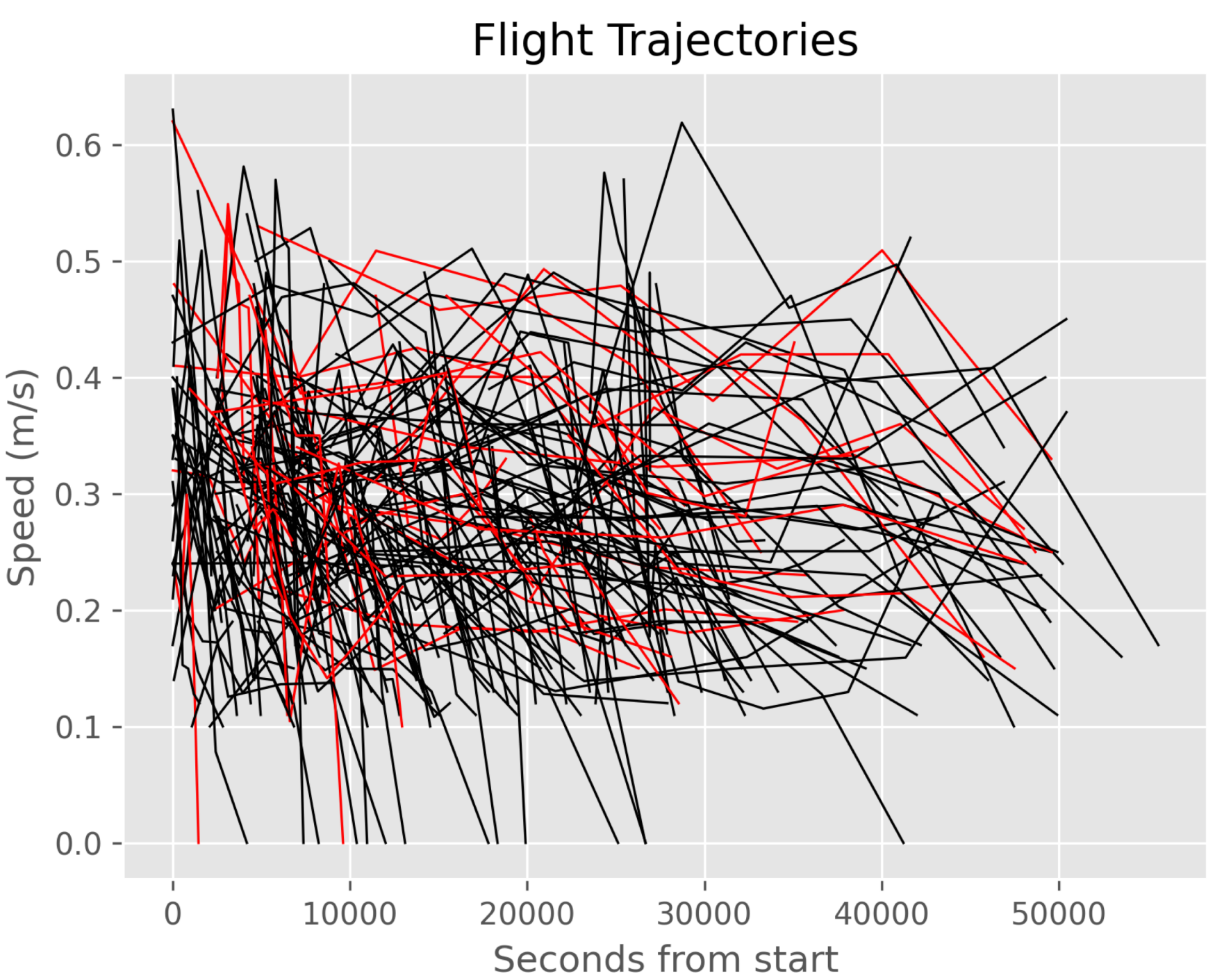


5 points | Mass

Mean = 0.0527 g

Less than the mean

Greater than the mean



5 points | Mass

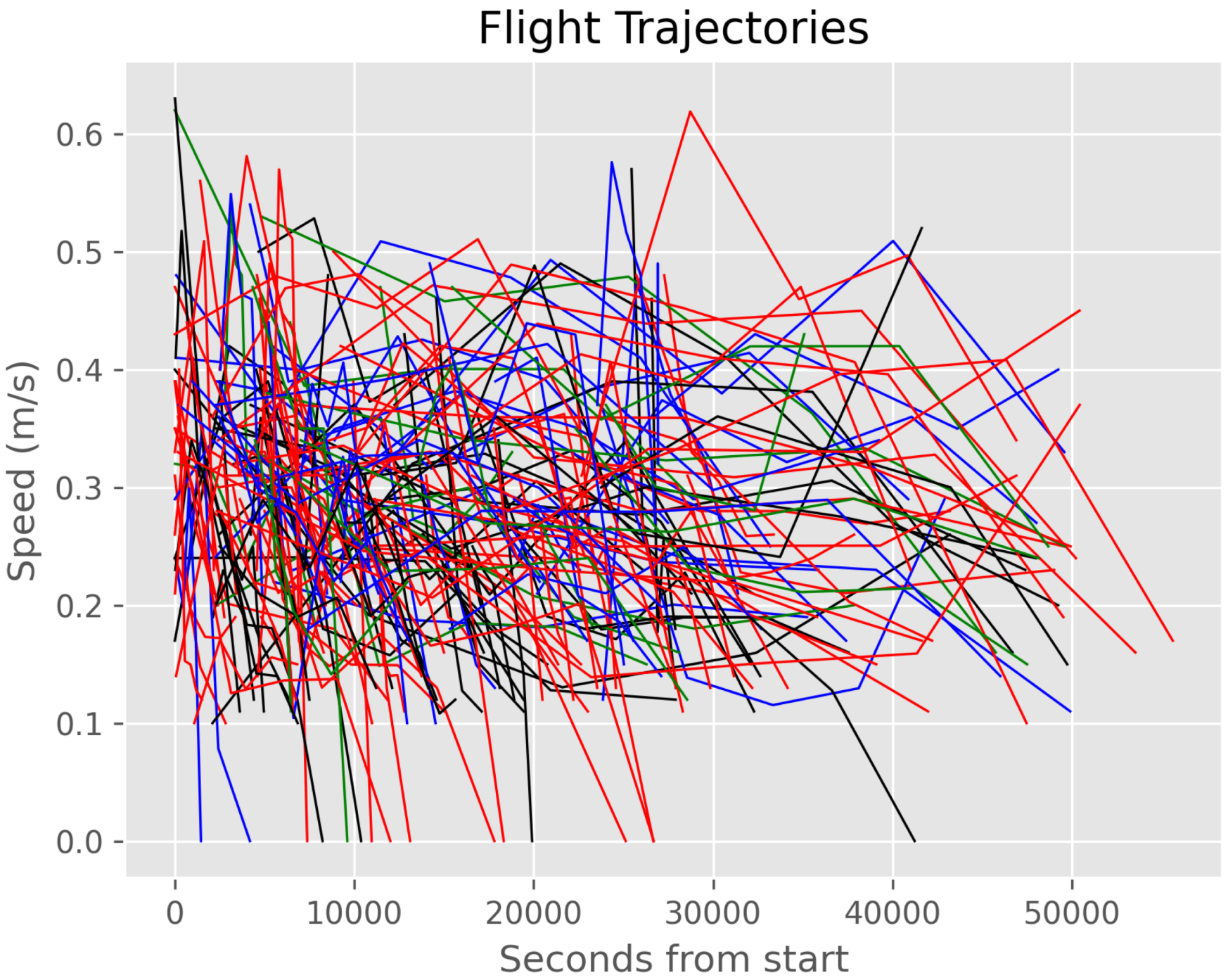
Mass sweat spot for flight?

1st Quartile

2nd Quartile

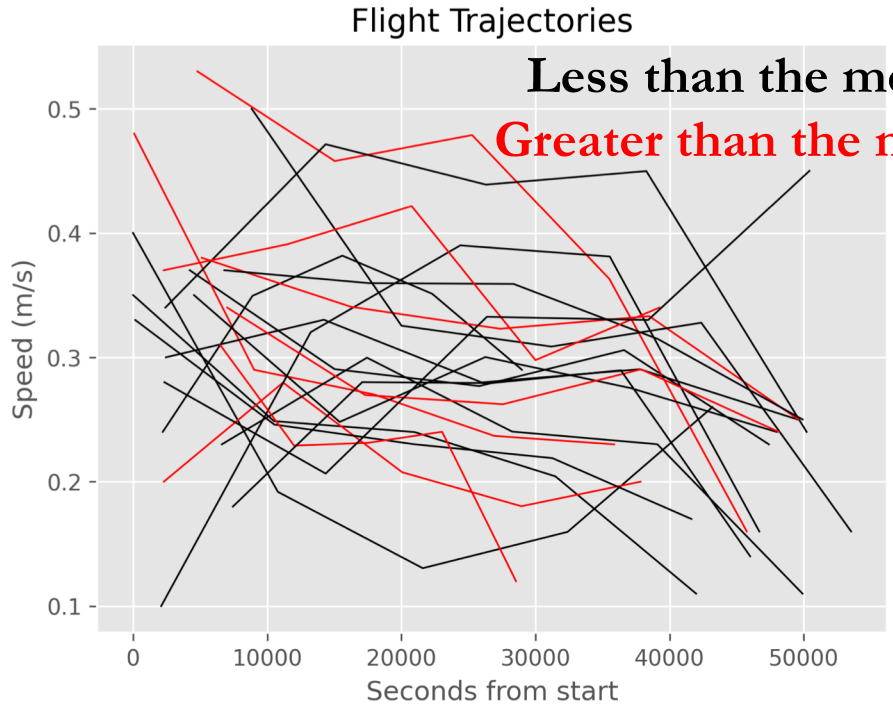
3rd Quartile

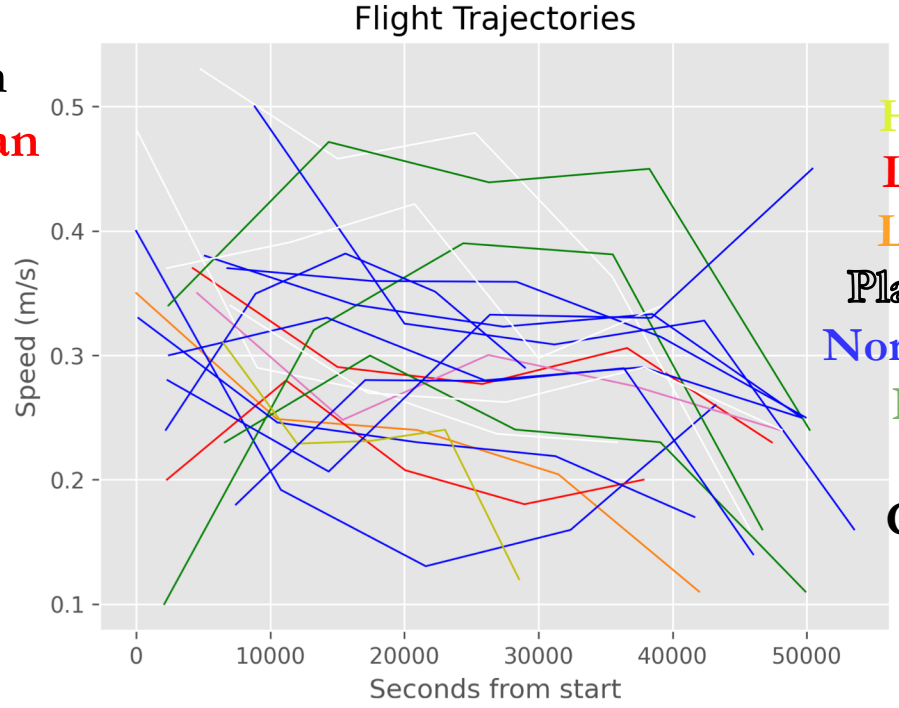
4th Quartile

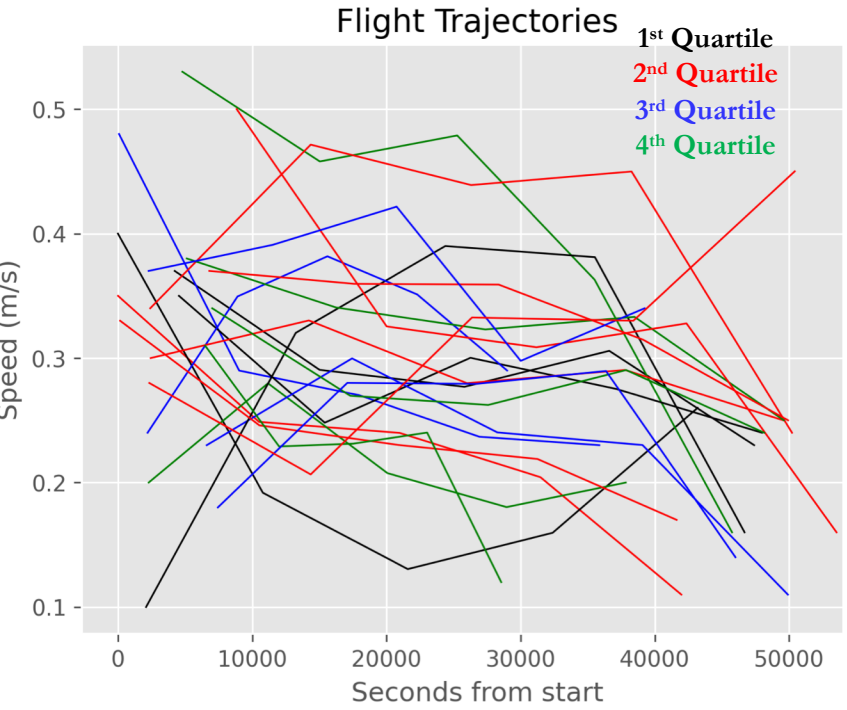


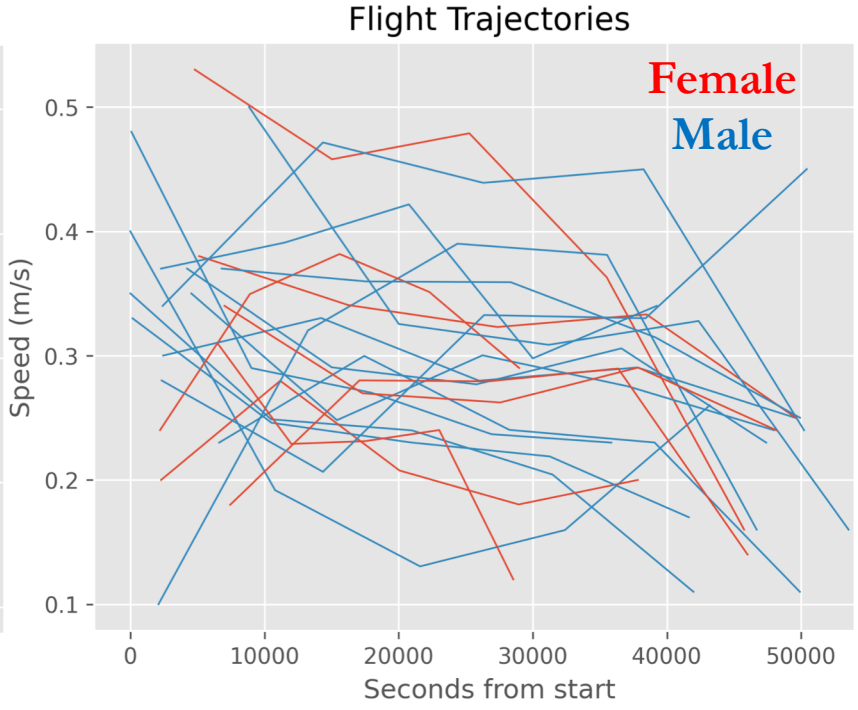
5 points | Long-distance flyers

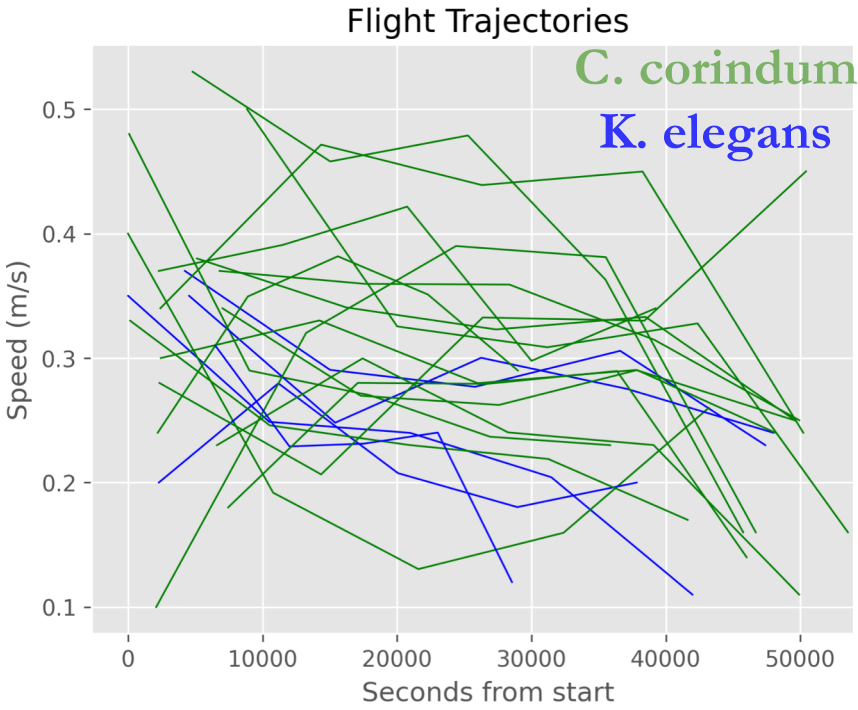
> 40,000 s



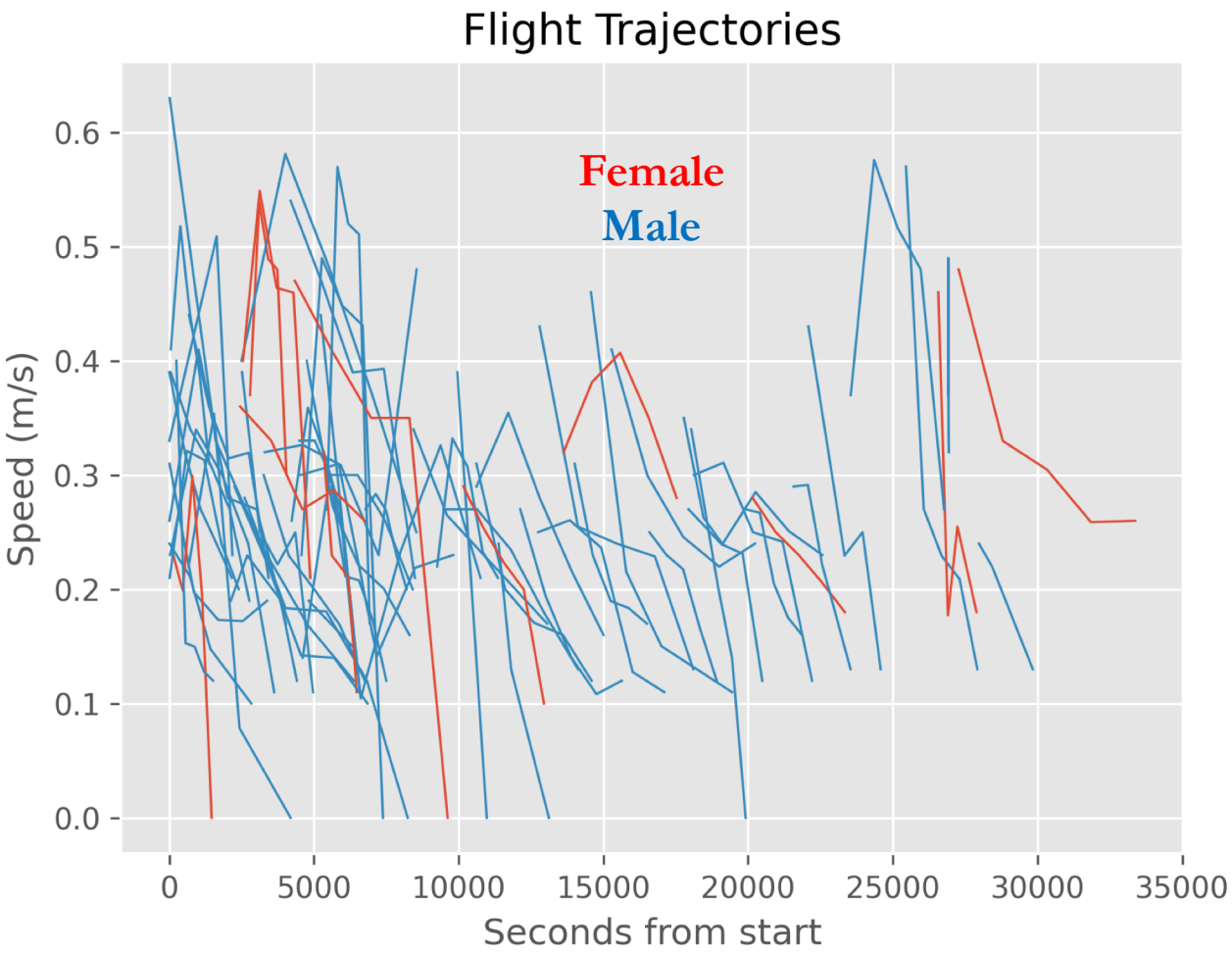


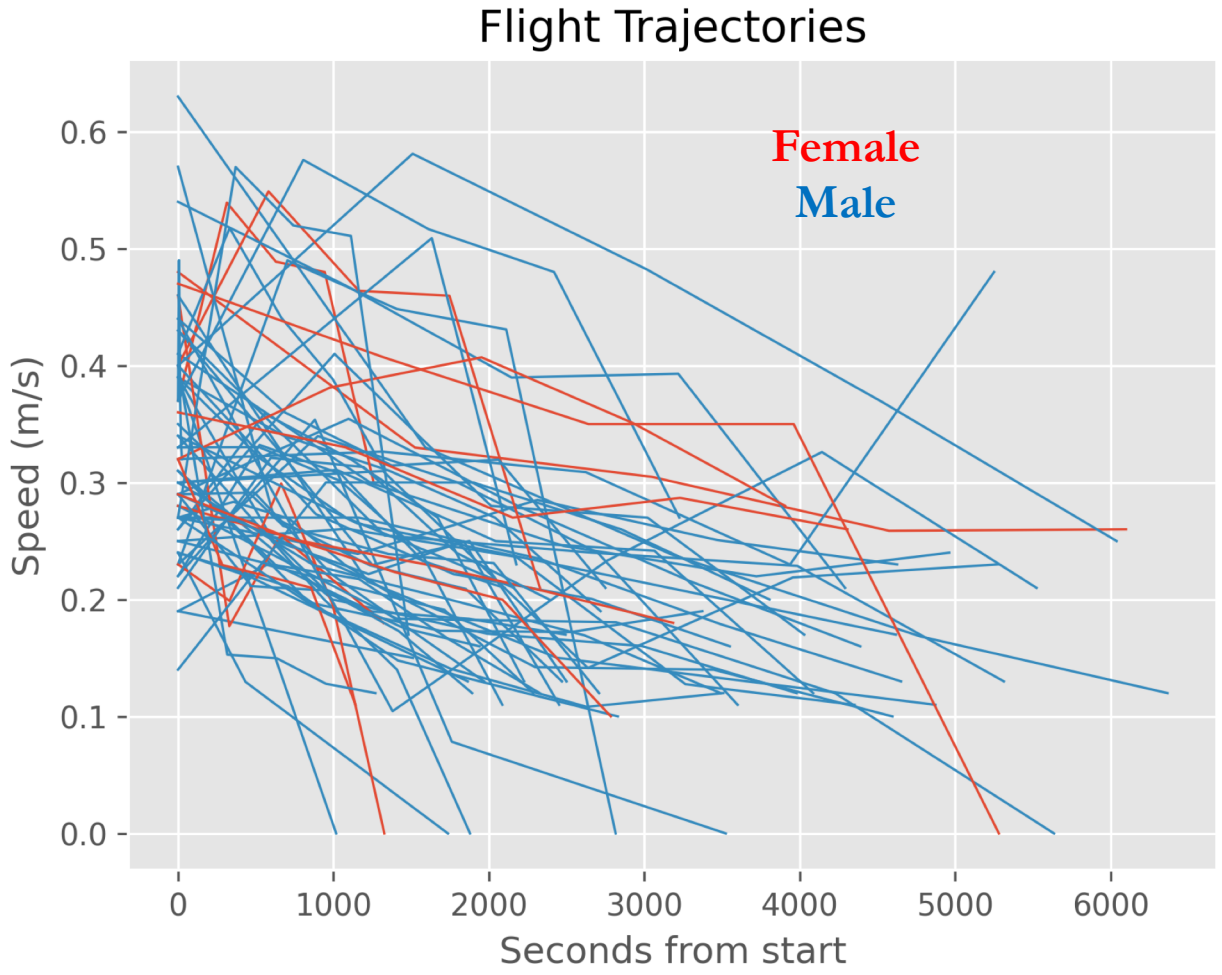




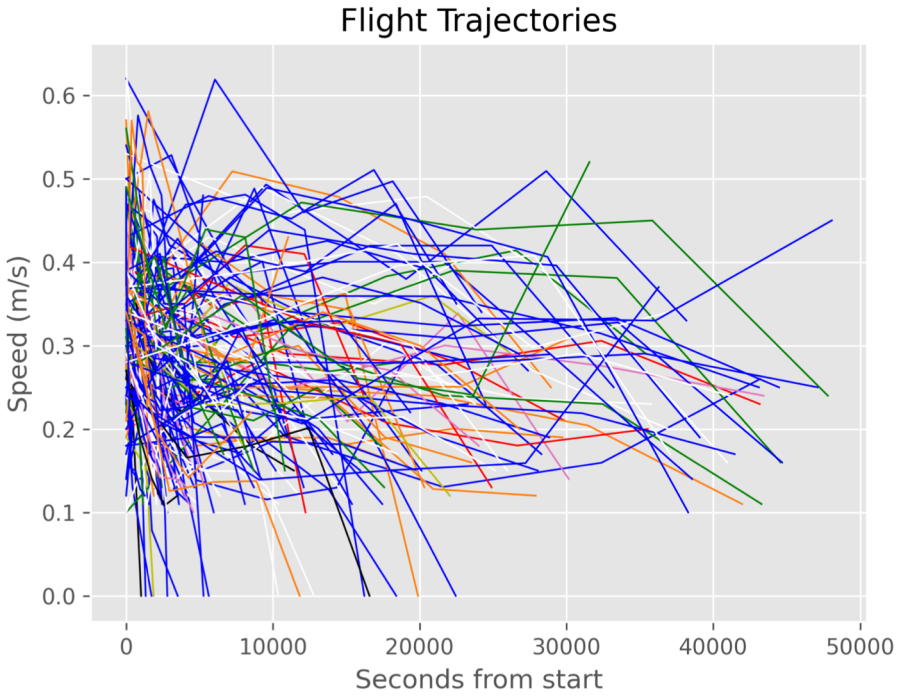


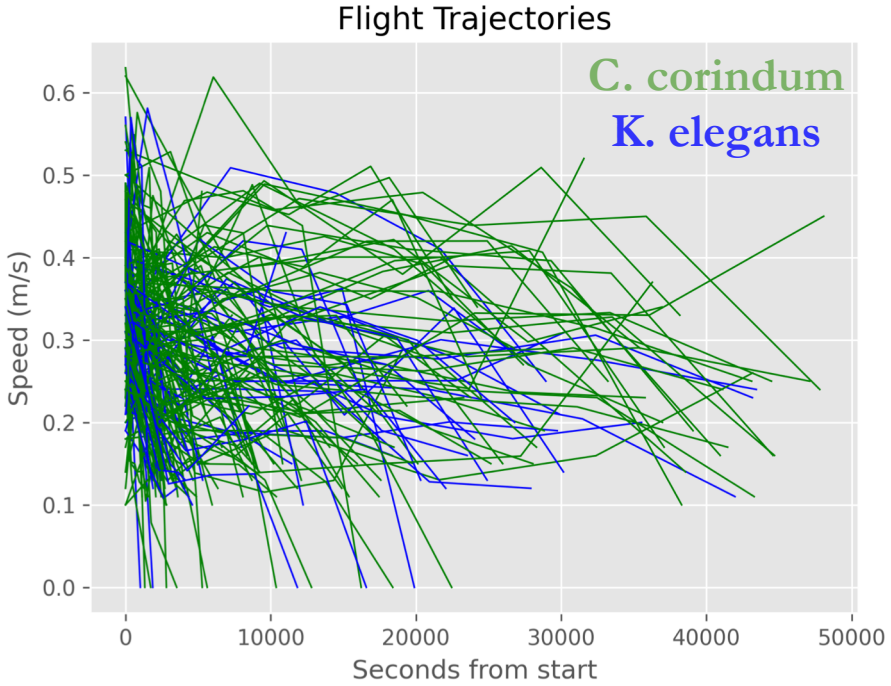
5 points | Short-distance flyers $< 7{,}200$ s

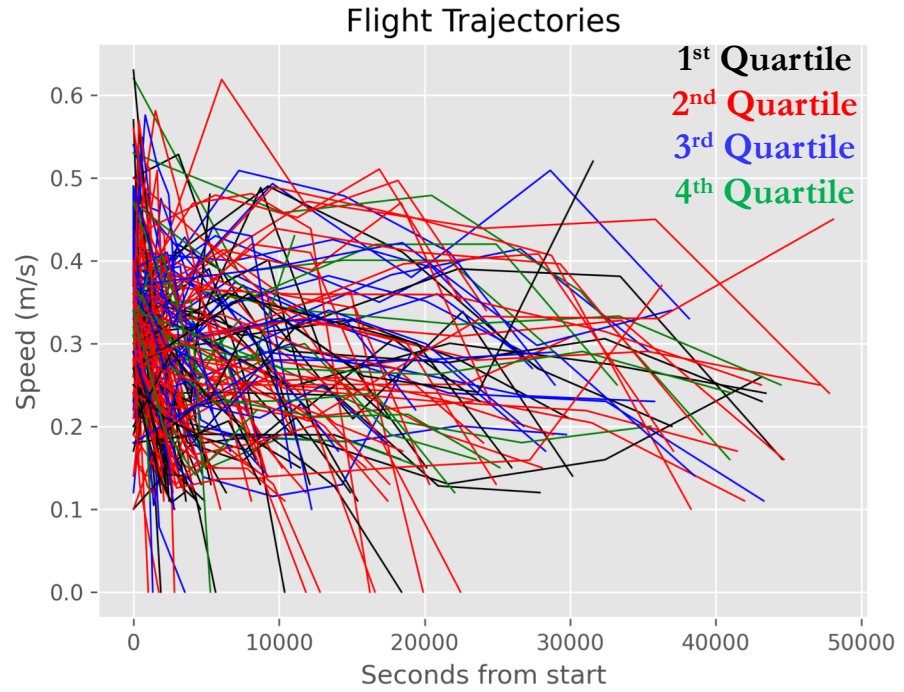


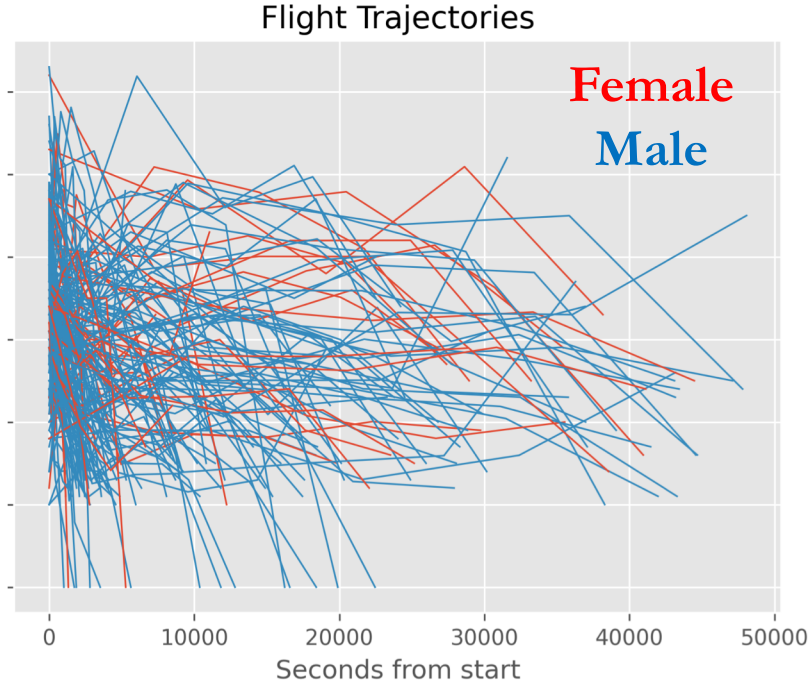


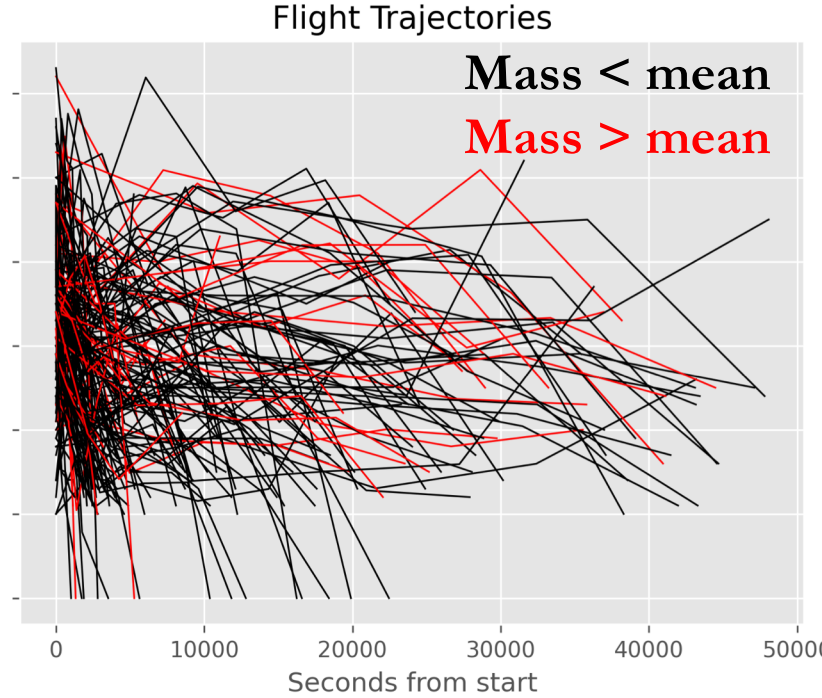
Lake Wales
Lake Placid
Plantation Key
North Key Largo
Key Largo
Homestead
Leesburg
Gainesville











TBC…

- Plot acceleration graphs, especially for long-distance flyers
- Bar graphs of speed vs. time
- Polynomial regressions for mass vs. morphology
- Could do PCA analysis
- Continue distance and speed modeling

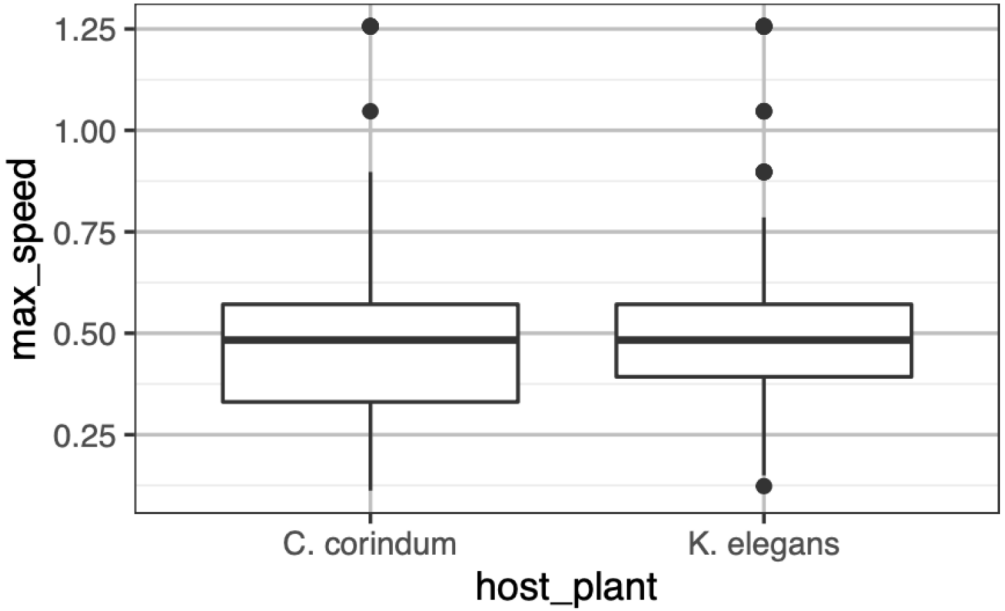
- Need to consider whether the bugs who flew in one trial or not the other, are the change in distances because the change in mass or the change in time of testing?

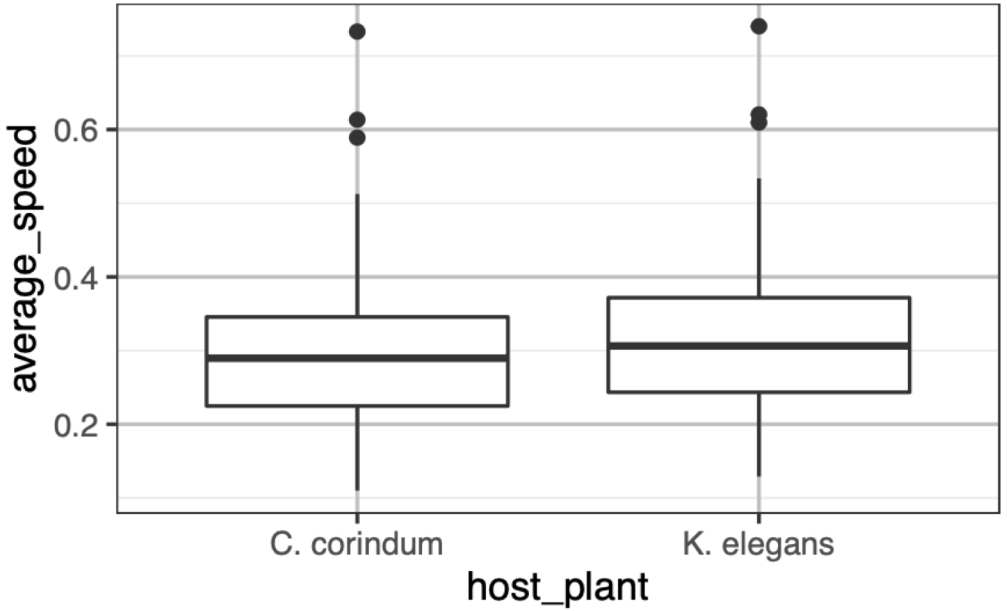
Questions?

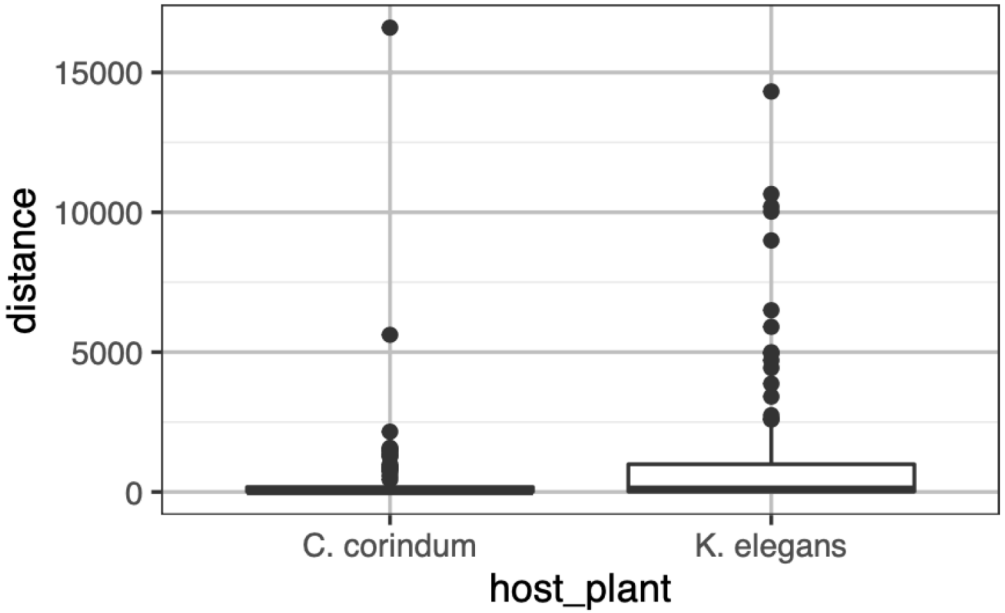
Autumn 2019

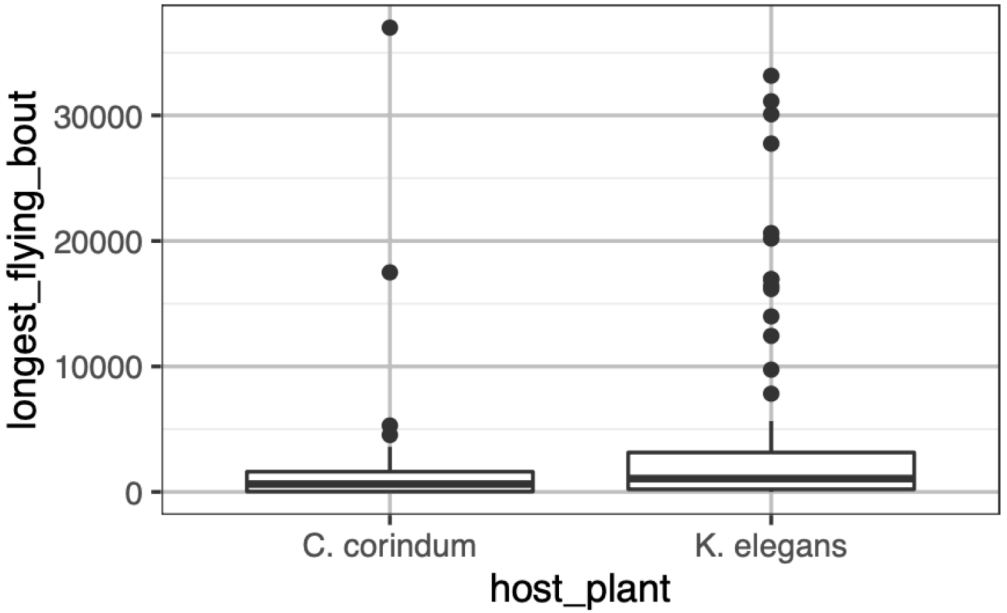
Host Plant Differences

(Autumn 2019)

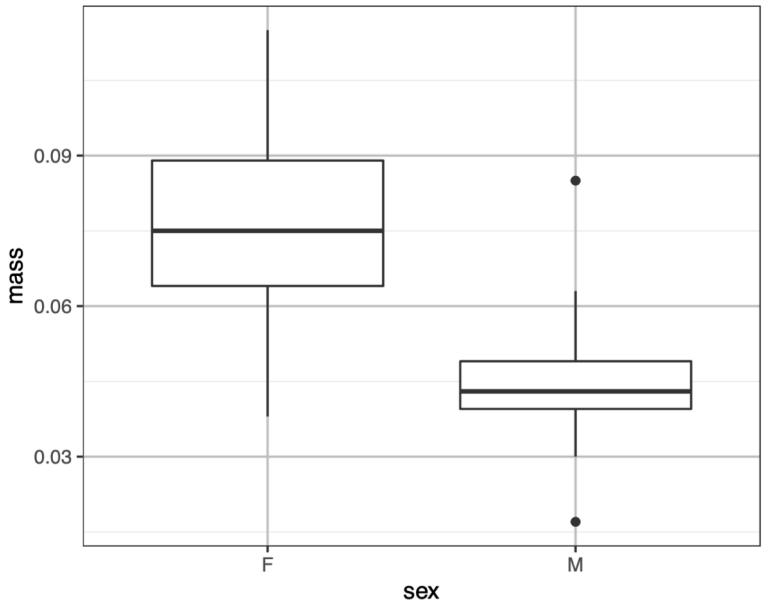


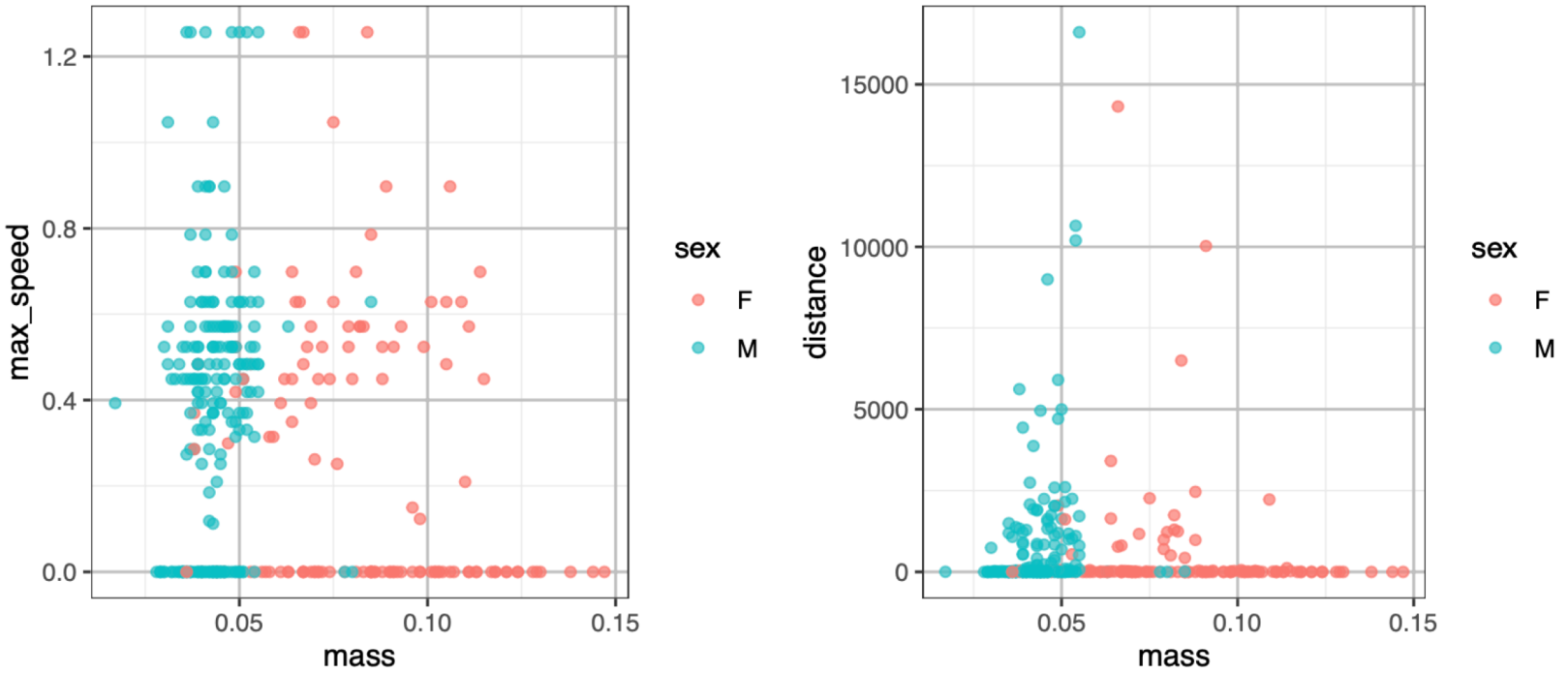


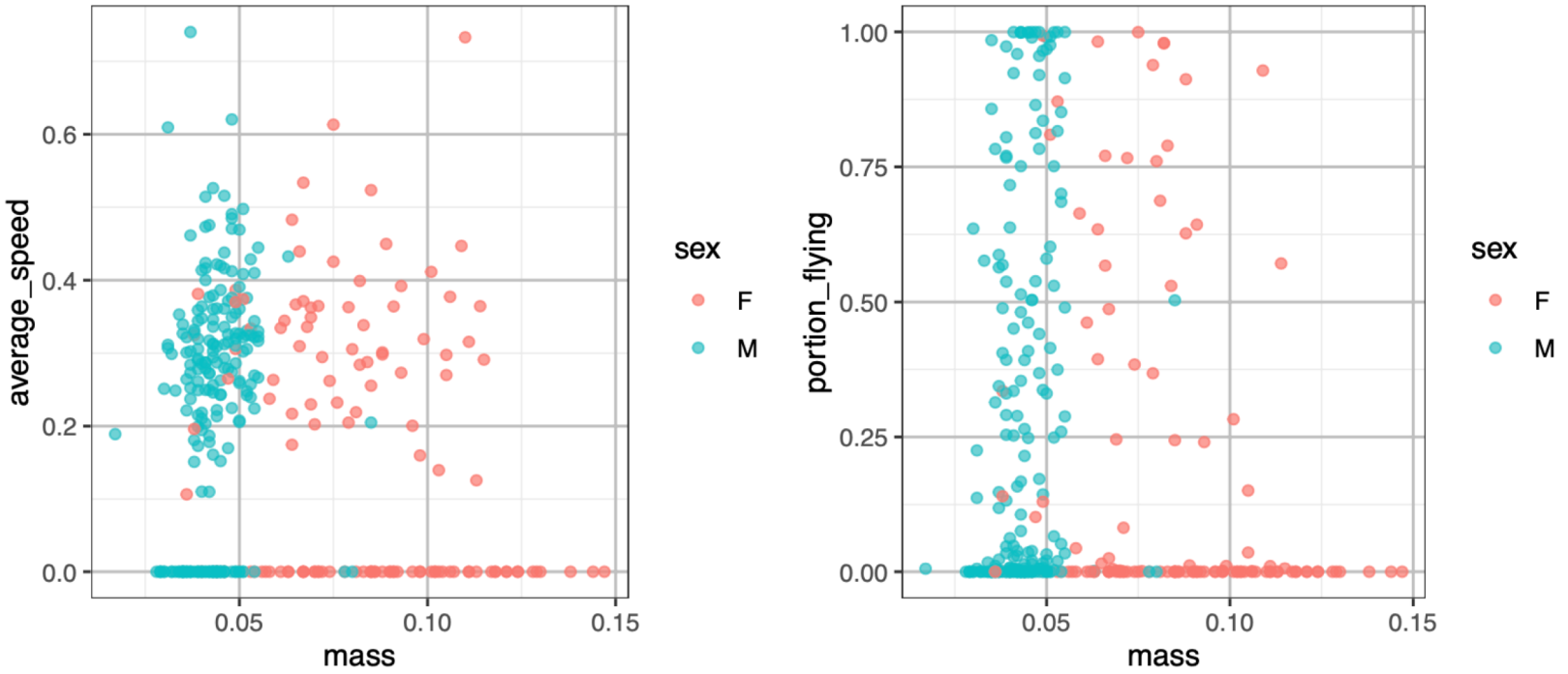




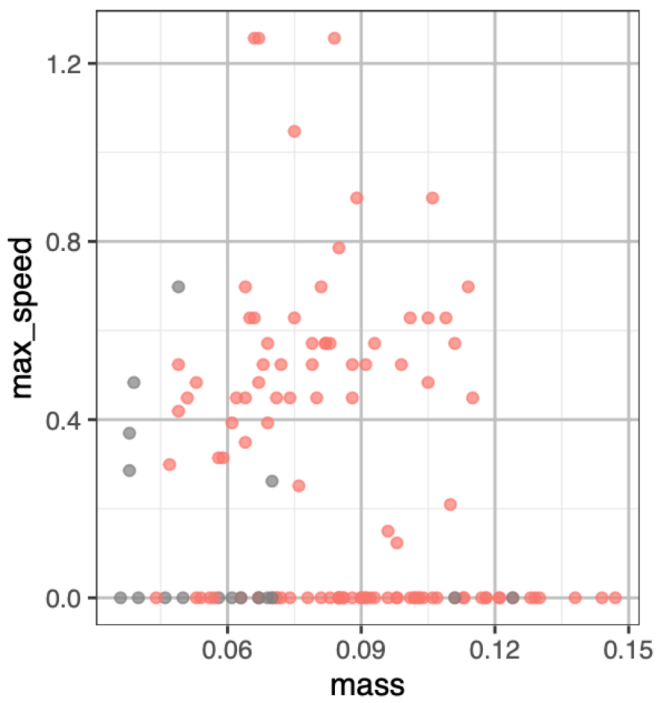
Sex Differences
(Autumn 2019)

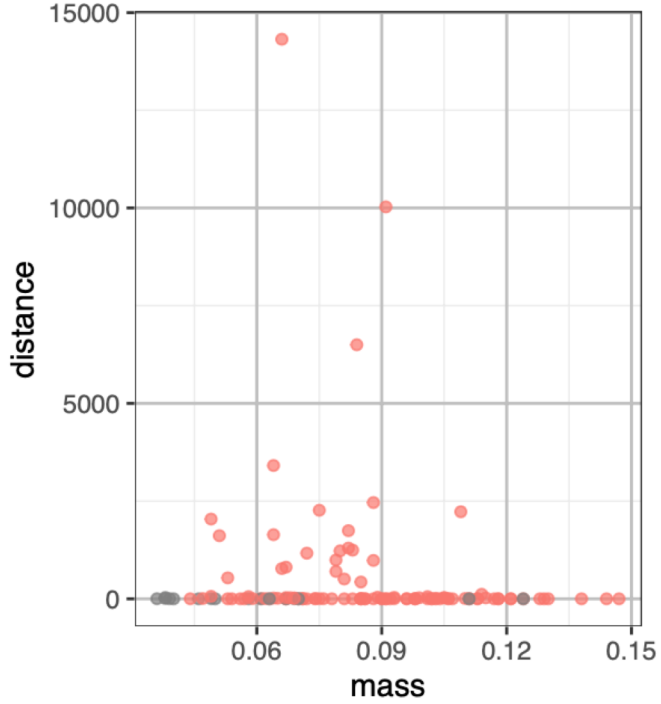


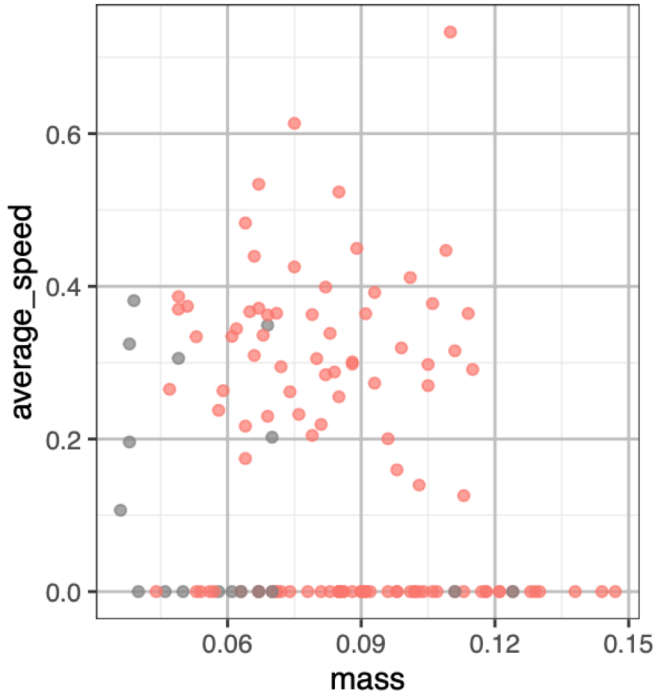


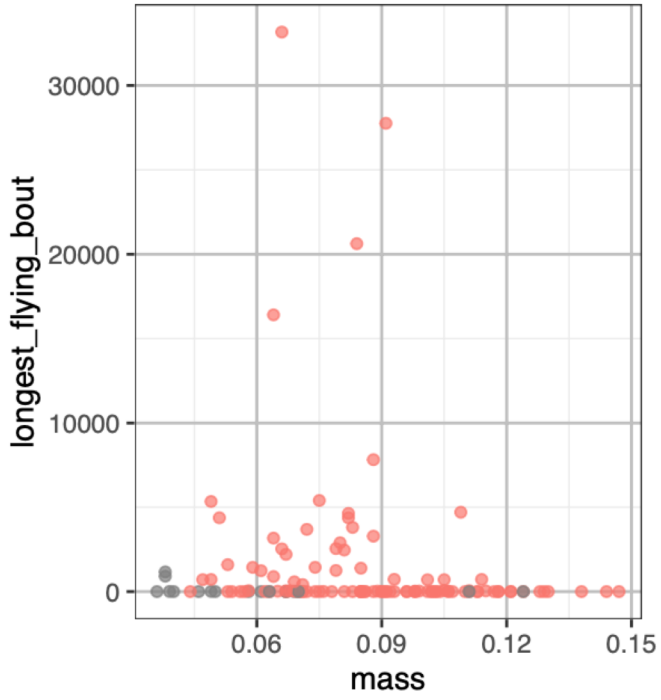


Sex Differences
(Autumn 2019)





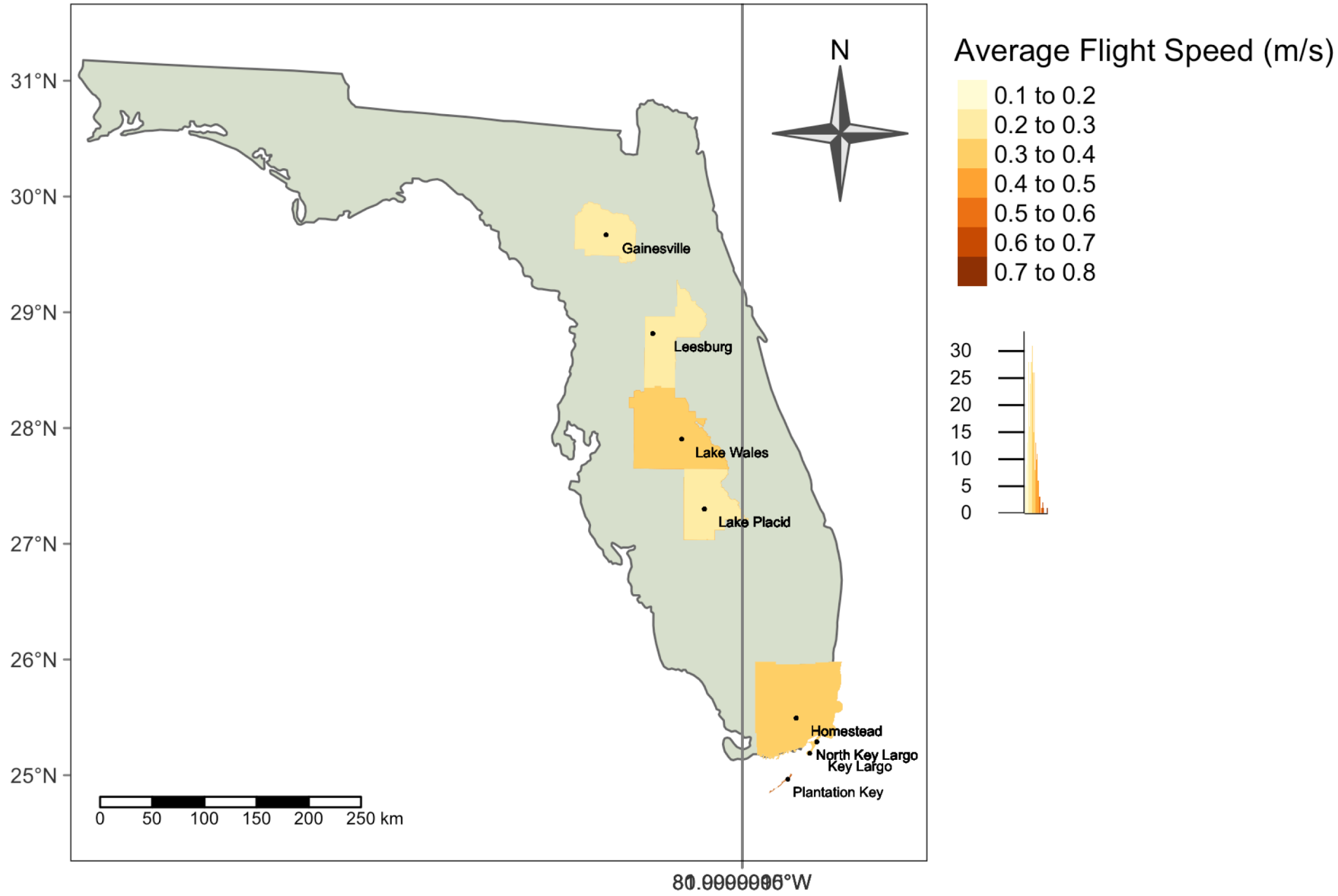




Spatial Differences (Autumn 2019)

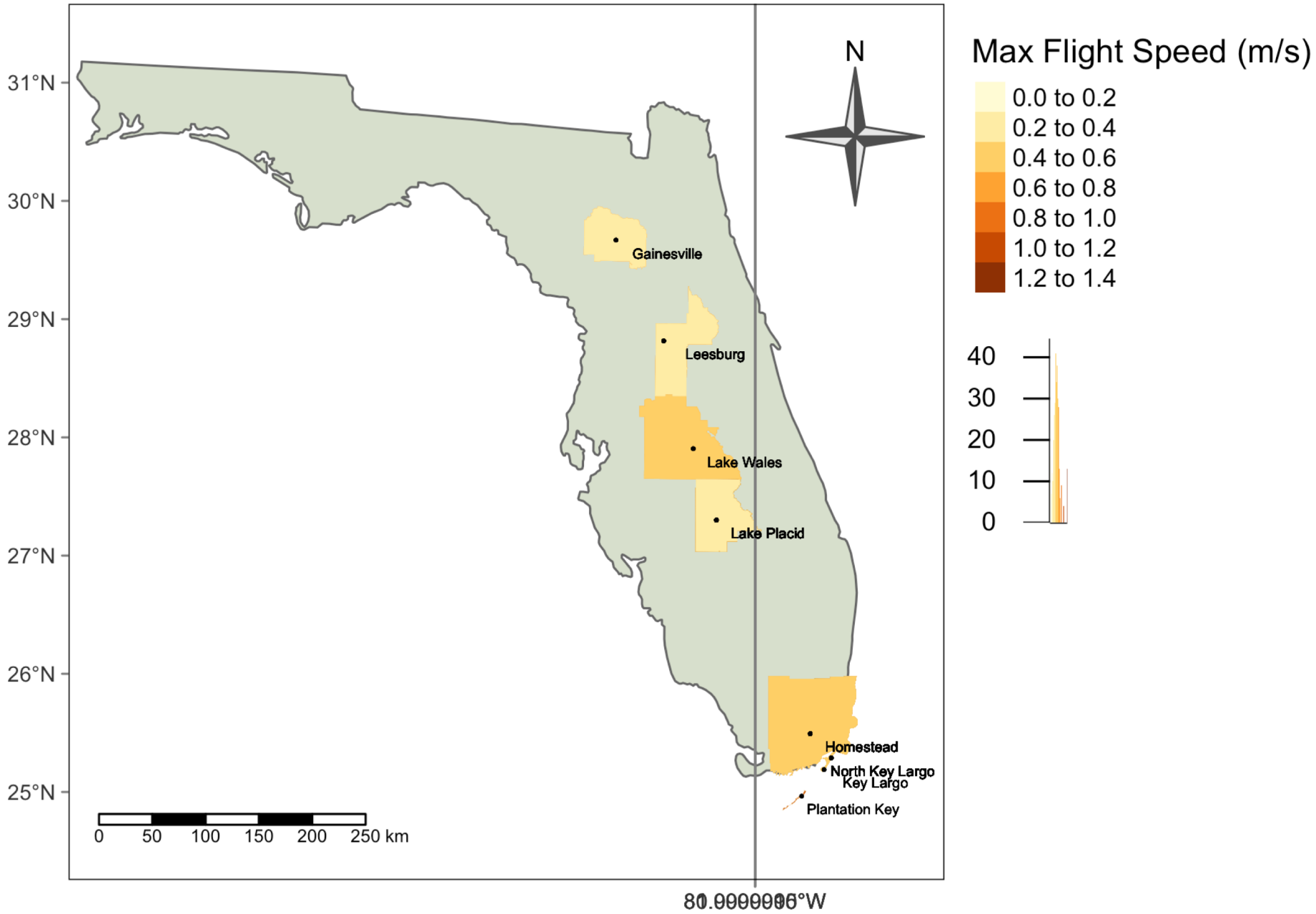
All trials

Average Flight Speed Across Latitude (m/s)



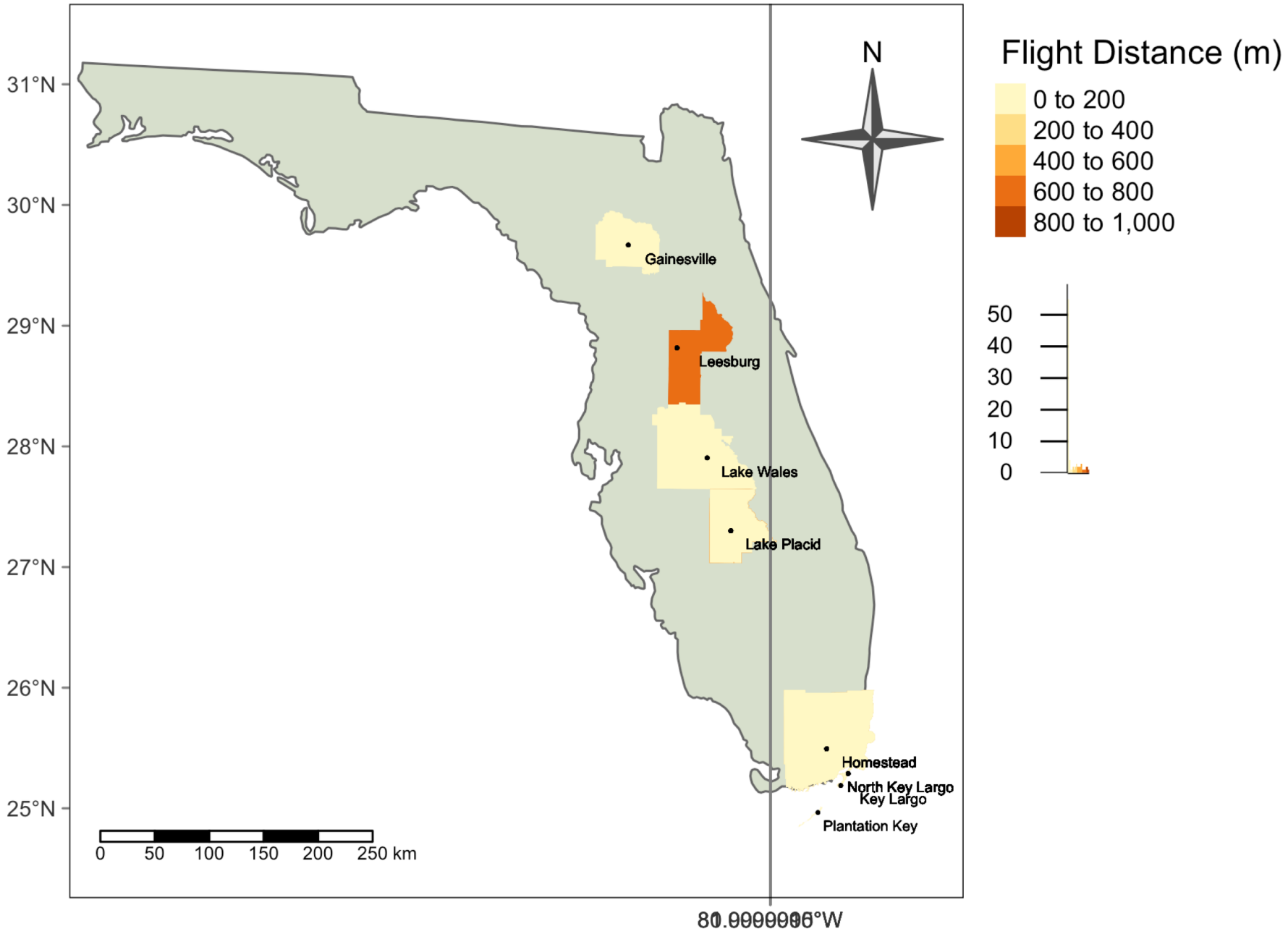
Max Flight Speed Across Latitude (m/s)

All trials



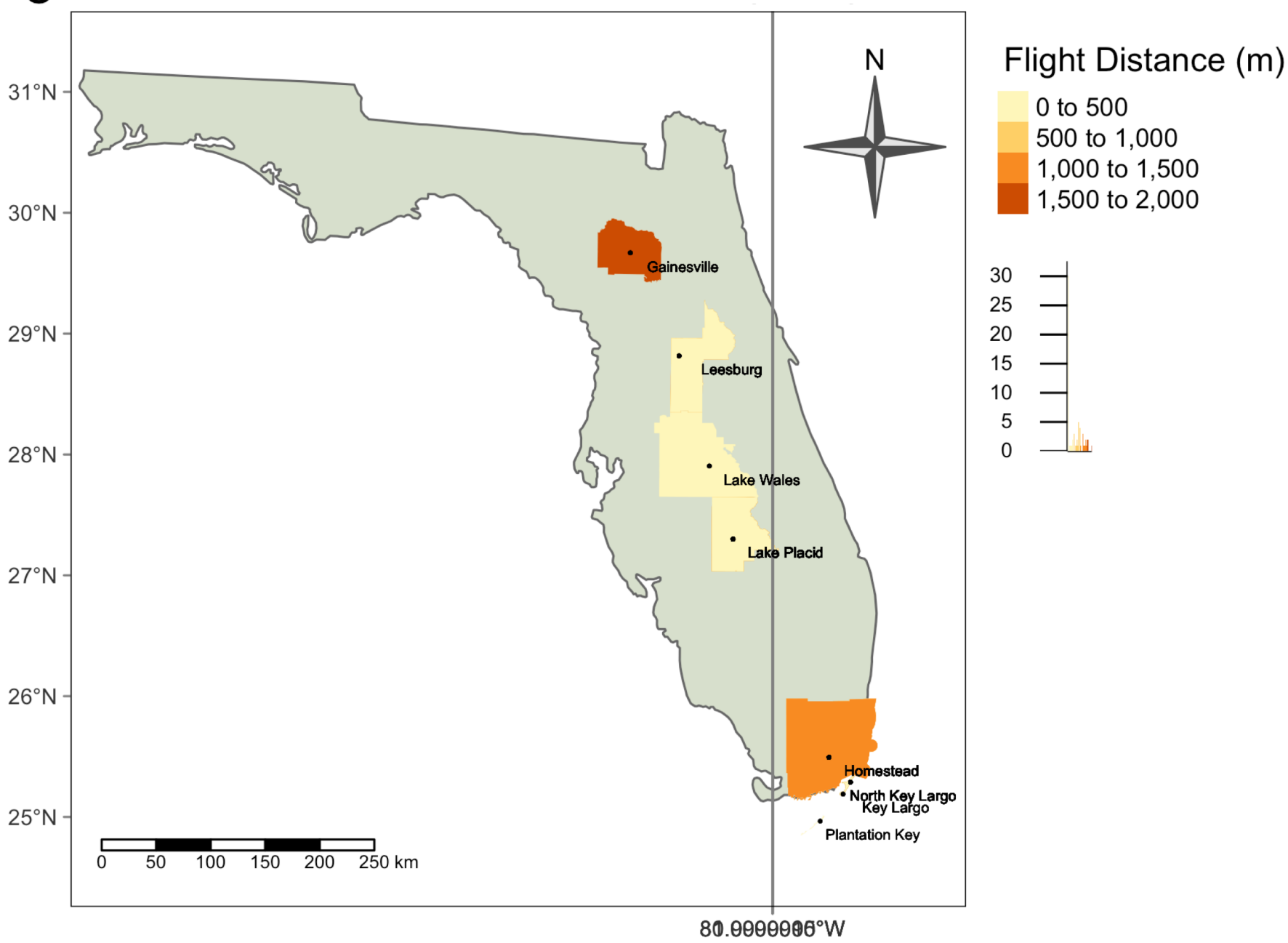
Flight Distance Across Latitude

30-minute trials



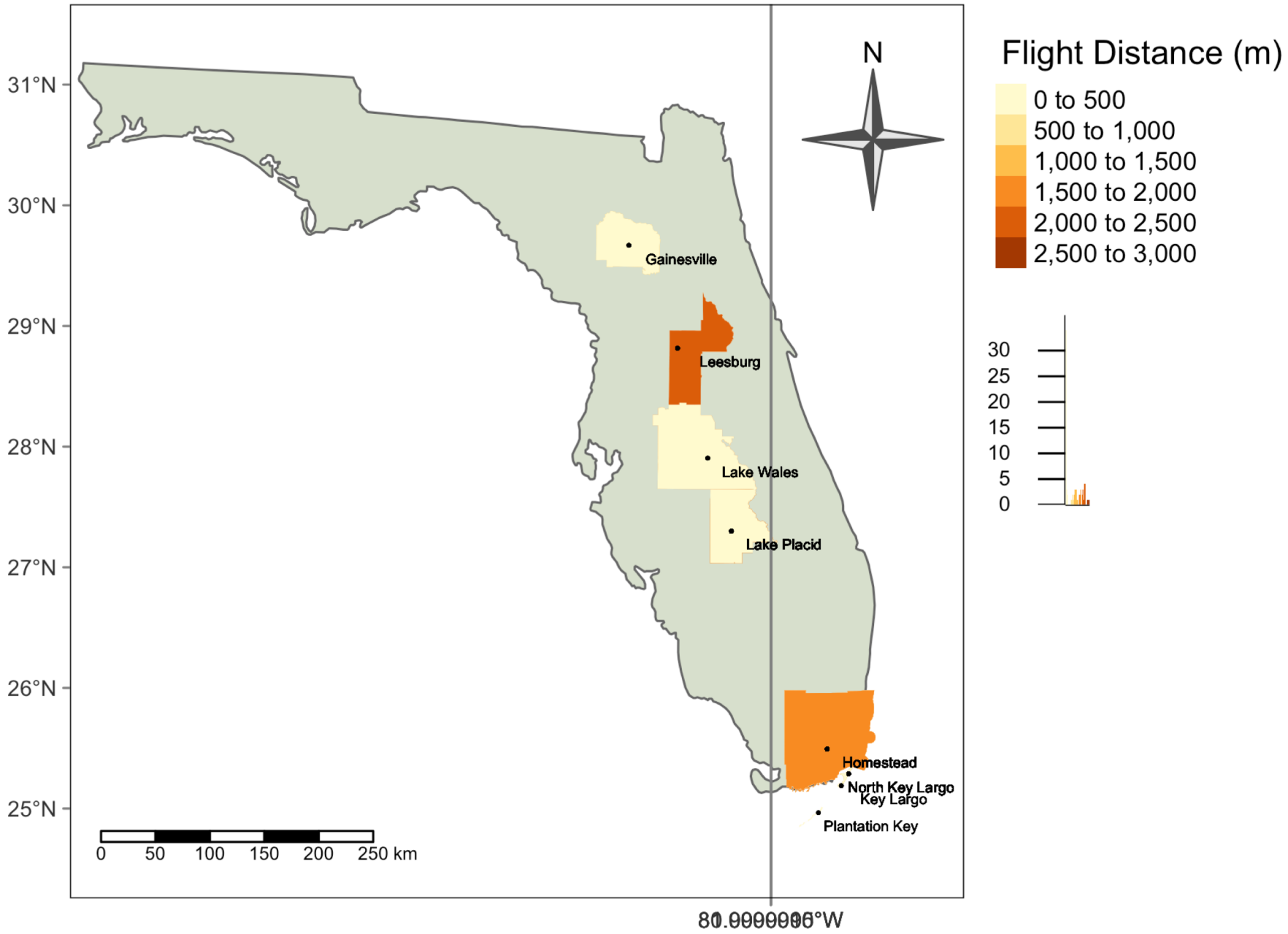
Flight Distance Across Latitude

60-minute trials



Flight Distance Across Latitude

90-minute trials



Flight Distance Across Latitude

Multi-hour trials