

Urbanization influences communities of milkweed-specialist herbivorous insects

ON_herb Figures

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```
## Load the tidyverse
library(tidyverse)

## Map
library(maps)
library(mapdata)
library(maptools)
library(ggmap)

## Figures
library(calecopal)
library(ggpubr)
library(grid)
library(gridExtra)
library(scales)

## Load the final workspace
load("data_analysis/1-analyses/ON_herb-analyses-workspace.RData")

## Read in site information
```

```
site.information <- read_csv(  
  "data/site_information.csv",  
  col_types = c("fffnnnf"),  
  show_col_types = FALSE  
)
```

Colour Palettes

Site Map

```
## Compute bounding box
ON_bbox <- make_bbox(lat = Latitude, lon = Longitude, data = site.information)

## Get map from google
ON_big <- get_map(location = ON_bbox, source = "google", maptype = "satellite")

## Plot points and colour by city
site.map <- ggmap(ON_big) +
  geom_point(
    data = site.information,
    mapping = aes(x = Longitude, y = Latitude, color = City, pch = Habitat)
  ) +
  scale_colour_manual(values = superbloom.map, name = "City") +
  scale_shape_manual(values = c(17, 19), name = "Habitat") +
  labs(x = "Longitude", y = "Latitude") +
  theme_pubr()
```

Abundance, Richness, & Diversity | Toronto

```
## Abundance
# Early
toronto.early.abundance.figure <- ggscatter(
  data = filter(toronto.herbivores, Season == "Early"),
  x = "Distance",
  y = "Summed_Abundance",
  size = 2,
  color = "#A292C8",
  xlab = "Distance",
  ylab = "Community Abundance",
  title = "(A) Early Season Abundance",
  ggtheme = theme_pubr(),
  legend = "right",
  conf.int = TRUE
) +
  geom_smooth(method = "glm", formula = y ~ x, se = TRUE,
              method.args = list(family = "quasipoisson"),
              colour = "#A5BA92", fill = "#A5BA92") +
  font("xlab", size = 18, color = "gray0") +
  font("ylab", size = 18, color = "gray0") +
  font("xy.text", size = 14, color = "gray20") +
  rremove("x.text") +
  rremove("xlab")

# Late
toronto.late.abundance.figure <- ggscatter(
  data = filter(toronto.herbivores, Season == "Late"),
  x = "Distance",
  y = "Summed_Abundance",
  size = 2,
  color = "#A292C8",
  xlab = "Distance",
  ylab = "Community Abundance",
  title = "(B) Late Season Abundance",
  ggtheme = theme_pubr(),
  legend = "right",
  conf.int = TRUE
) +
  geom_smooth(method = "glm", formula = y ~ x, se = TRUE,
              method.args = list(family = "quasipoisson"),
              colour = "#A5BA92", fill = "#A5BA92") +
  font("xlab", size = 18, color = "gray0") +
  font("ylab", size = 18, color = "gray0") +
  font("xy.text", size = 14, color = "gray20") +
  rremove("xy.text") +
  rremove("xlab") +
  rremove("ylab")

## Richness
# Early
```

```

toronto.early.richness.figure <- ggscatter(
  data = filter(toronto.herbivores, Season == "Early"),
  x = "Distance",
  y = "Richness",
  size = 2,
  color = "#A292C8",
  xlab = "Distance",
  ylab = "Species Richness",
  title = "(C) Early Season Richness",
  ggtheme = theme_pubr(),
  legend = "right",
  conf.int = TRUE
) +
  geom_smooth(method = "glm", formula = y ~ x, se = TRUE,
              method.args = list(family = "poisson"),
              colour = "#A5BA92", fill = "#A5BA92") +
  font("xlab", size = 18, color = "gray0") +
  font("ylab", size = 18, color = "gray0") +
  font("xy.text", size = 14, color = "gray20") +
  rremove("x.text") +
  rremove("xlab")

```

Late

```

toronto.late.richness.figure <- ggscatter(
  data = filter(toronto.herbivores, Season == "Late"),
  x = "Distance",
  y = "Richness",
  size = 2,
  color = "#A292C8",
  xlab = "Distance",
  ylab = "Species Richness",
  title = "(D) Late Season Richness",
  ggtheme = theme_pubr(),
  legend = "right",
  conf.int = TRUE
) +
  geom_smooth(method = "glm", formula = y ~ x, se = TRUE,
              method.args = list(family = "poisson"),
              colour = "#A5BA92", fill = "#A5BA92") +
  font("xlab", size = 18, color = "gray0") +
  font("ylab", size = 18, color = "gray0") +
  font("xy.text", size = 14, color = "gray20") +
  rremove("xy.text") +
  rremove("xlab") +
  rremove("ylab")

```

Diversity

Early

```

toronto.early.diversity.figure <- ggscatter(
  data = filter(toronto.herbivores, Season == "Early"),
  x = "Distance",
  y = "Diversity",

```

```

    size = 2,
    color = "#A292C8",
    xlab = "Distance",
    ylab = "Diversity",
    title = "(E) Early Season Diversity",
    ggtheme = theme_pubr(),
    legend = "right",
    conf.int = TRUE
) +
  geom_smooth(method = "lm", formula = y ~ x, se = TRUE,
              colour = "#A5BA92", fill = "#A5BA92") +
  font("xlab", size = 18, color = "gray0") +
  font("ylab", size = 18, color = "gray0") +
  font("xy.text", size = 14, color = "gray20")

# Late
toronto.late.diversity.figure <- ggscatter(
  data = filter(toronto.herbivores, Season == "Late"),
  x = "Distance",
  y = "Diversity",
  size = 2,
  color = "#A292C8",
  xlab = "Distance",
  ylab = "Diversity",
  title = "(F) Late Season Diversity",
  ggtheme = theme_pubr(),
  legend = "right",
  conf.int = TRUE
) +
  geom_smooth(method = "lm", formula = y ~ x, se = TRUE,
              colour = "#A5BA92", fill = "#A5BA92") +
  font("xlab", size = 18, color = "gray0") +
  font("ylab", size = 18, color = "gray0") +
  font("xy.text", size = 14, color = "gray20") +
  rremove("y.text") +
  rremove("ylab")

```

```

## Arrange the panel figure
toronto.ARD.figure <- ggarrange(
  toronto.early.abundance.figure, toronto.late.abundance.figure,
  toronto.early.richness.figure, toronto.late.richness.figure,
  toronto.early.diversity.figure, toronto.late.diversity.figure,
  nrow = 3,
  ncol = 2,
  align = "v",
  legend = "none"
)

```

```

## Export the figure
ggsave("fig_2-toronto_ARD-base.pdf",
       plot = toronto.ARD.figure,
       device = "pdf",

```

```
path = "figures/",  
width = 12,  
height = 10,  
units = "in",  
dpi = 900)
```

Abundance, Richness, & Diversity | 5 Cities

```
## Abundance
# Early
five.cities.early.abundance.figure <- ggerrorplot(
  data = filter(five.cities.herbivores, Season == "Early"),
  x = "Habitat",
  y = "Summed_Abundance",
  size = 1.5,
  width = 2,
  desc_stat = "mean_se",
  color = "City",
  palette = superbloom.5,
  xlab = "Habitat",
  ylab = "Community Abundance",
  title = "(A) Early Season Abundance",
  ggtheme = theme_pubr()
) %>%
facet(
  facet.by = "City",
  nrow = 1,
  ncol = 5
) +
stat_summary(aes(group = City), fun = mean, geom = "path",
              color = superbloom.10.lines) +
scale_y_continuous(breaks = c(0, 60, 120, 180)) +
font("xlab", size = 18, color = "gray0") +
font("ylab", size = 18, color = "gray0") +
font("xy.text", size = 14, color = "gray20") +
rremove("x.text") +
rremove("xlab")

# Late
five.cities.late.abundance.figure <- ggerrorplot(
  data = filter(five.cities.herbivores, Season == "Late"),
  x = "Habitat",
  y = "Summed_Abundance",
  size = 1.5,
  width = 2,
  desc_stat = "mean_se",
  color = "City",
  palette = superbloom.5,
  xlab = "Habitat",
  ylab = "Community Abundance",
  title = "(B) Late Season Abundance",
  ggtheme = theme_pubr()
) %>%
facet(
  facet.by = "City",
  nrow = 1,
  ncol = 5
) +
stat_summary(aes(group = City), fun = mean, geom = "path",
```



```

                                color = superbloom.10.lines) +
scale_y_continuous(breaks = c(0, 1000, 2000, 3000, 4000)) +
font("xlab", size = 18, color = "gray0") +
font("ylab", size = 18, color = "gray0") +
font("xy.text", size = 14, color = "gray20") +
rremove("x.text") +
rremove("xlab") +
rremove("ylab")

## Richness
# Early
five.cities.early.richness.figure <- ggerrorplot(
  data = filter(five.cities.herbivores, Season == "Early"),
  x = "Habitat",
  y = "Richness",
  size = 1.5,
  width = 2,
  desc_stat = "mean_se",
  color = "City",
  palette = superbloom.5,
  xlab = "Habitat",
  ylab = "Richness",
  title = "(C) Early Season Richness",
  ggtheme = theme_pubr()
) %>%
facet(
  facet.by = "City",
  nrow = 1,
  ncol = 5
) +
stat_summary(aes(group = City), fun = mean, geom = "path",
              color = superbloom.10.lines) +
scale_y_continuous(breaks = c(1, 2, 3, 4)) +
font("xlab", size = 18, color = "gray0") +
font("ylab", size = 18, color = "gray0") +
font("xy.text", size = 14, color = "gray20") +
rremove("x.text") +
rremove("xlab")

# Late
five.cities.late.richness.figure <- ggerrorplot(
  data = filter(five.cities.herbivores, Season == "Late"),
  x = "Habitat",
  y = "Richness",
  size = 1.5,
  width = 2,
  desc_stat = "mean_se",
  color = "City",
  palette = superbloom.5,
  xlab = "Habitat",
  ylab = "Richness",
  title = "(D) Late Season Richness",

```

```

ggtheme = theme_pubr()
) %>%
facet(
  facet.by = "City",
  nrow = 1,
  ncol = 5
) +
stat_summary(aes(group = City), fun = mean, geom = "path",
              color = superbloom.10.lines) +
scale_y_continuous(breaks = c(1, 2, 3, 4)) +
font("xlab", size = 18, color = "gray0") +
font("ylab", size = 18, color = "gray0") +
font("xy.text", size = 14, color = "gray20") +
rremove("x.text") +
rremove("xlab") +
rremove("ylab")

## Diversity
# Early
five.cities.early.diversity.figure <- ggerrorplot(
  data = filter(five.cities.herbivores, Season == "Early"),
  x = "Habitat",
  y = "Diversity",
  size = 1.5,
  width = 2,
  desc_stat = "mean_se",
  color = "City",
  palette = superbloom.5,
  xlab = "Habitat",
  ylab = "Diversity",
  title = "(E) Early Season Diversity",
  ggtheme = theme_pubr()
) %>%
facet(
  facet.by = "City",
  nrow = 1,
  ncol = 5
) +
stat_summary(aes(group = City), fun = mean, geom = "path",
              color = superbloom.10.lines) +
scale_y_continuous(breaks = c(0, 0.25, 0.50, 0.75, 1.00, 1.25)) +
font("xlab", size = 18, color = "gray0") +
font("ylab", size = 18, color = "gray0") +
font("xy.text", size = 14, color = "gray20")

# Late
five.cities.late.diversity.figure <- ggerrorplot(
  data = filter(five.cities.herbivores, Season == "Late"),
  x = "Habitat",
  y = "Diversity",
  size = 1.5,
  width = 2,

```

```

desc_stat = "mean_se",
color = "City",
palette = superbloom.5,
xlab = "Habitat",
ylab = "Diversity",
title = "(F) Late Season Diversity",
ggtheme = theme_pubr()
) %>%
facet(
  facet.by = "City",
  nrow = 1,
  ncol = 5
) +
stat_summary(aes(group = City), fun = mean, geom = "path",
              color = superbloom.10.lines) +
scale_y_continuous(breaks = c(0, 0.5, 1.0)) +
font("xlab", size = 18, color = "gray0") +
font("ylab", size = 18, color = "gray0") +
font("xy.text", size = 14, color = "gray20") +
remove("ylab")

```

Arrange the panel figure

```

five.cities.ARD.figure <- ggarrange(
  five.cities.early.abundance.figure, five.cities.late.abundance.figure,
  five.cities.early.richness.figure, five.cities.late.richness.figure,
  five.cities.early.diversity.figure, five.cities.late.diversity.figure,
  nrow = 3,
  ncol = 2,
  align = "v",
  legend = "top",
  common.legend = TRUE
)

```

Export the figure

```

ggsave("fig_3-five.cities_ARD-base.pdf",
  plot = five.cities.ARD.figure,
  device = "pdf",
  path = "figures/",
  width = 15,
  height = 12.5,
  units = "in",
  dpi = 900)

```

Leaf Herbivory | Toronto

```
toronto.leaf.herbivory.figure <- ggscatter(  
  data = toronto.leaf.damage,  
  x = "Distance",  
  y = "Mean_Leaf_Herbivory",  
  color = "Season",  
  palette = toronto.2,  
  xlab = "Distance",  
  ylab = "Mean Leaf Herbivory (%)",  
  ggtheme = theme_pubr(),  
  legend = "right",  
  add = "reg.line",  
  conf.int = TRUE  
) +  
  font("xlab", size = 18, color = "gray0") +  
  font("ylab", size = 18, color = "gray0") +  
  font("xy.text", size = 14, color = "gray20")
```

```
## Export the figure  
ggsave("fig_4-toronto_leaf_herbivory-base.pdf",  
  plot = toronto.leaf.herbivory.figure,  
  device = "pdf",  
  path = "figures/",  
  width = 8,  
  height = 6,  
  units = "in",  
  dpi = 900)
```

Leaf Herbivory | 5 Cities

```
## Early
five.cities.early.leaf.herbivory.figure <- ggerrorplot(
  data = filter(five.cities.leaf.damage, Season == "Early"),
  x = "Habitat",
  y = "Mean_Leaf_Herbivory",
  size = 1.5,
  width = 2,
  desc_stat = "mean_se",
  color = "City",
  palette = superbloom.5,
  xlab = "Habitat",
  ylab = "Mean Leaf Herbivory (%)",
  title = "(A) Early Season Leaf Herbivory",
  ggtheme = theme_pubr()
) %>%
facet(
  facet.by = "City",
  nrow = 1,
  ncol = 5
) +
stat_summary(aes(group = City), fun = mean, geom = "path",
              color = superbloom.10.lines) +
font("xlab", size = 18, color = "gray0") +
font("ylab", size = 18, color = "gray0") +
font("xy.text", size = 14, color = "gray20")

## Late
five.cities.late.leaf.herbivory.figure <- ggerrorplot(
  data = filter(five.cities.leaf.damage, Season == "Late"),
  x = "Habitat",
  y = "Mean_Leaf_Herbivory",
  size = 1.5,
  width = 2,
  desc_stat = "mean_se",
  color = "City",
  palette = superbloom.5,
  xlab = "Habitat",
  ylab = "Mean Leaf Herbivory (%)",
  title = "(B) Late Season Leaf Herbivory",
  ggtheme = theme_pubr()
) %>%
facet(
  facet.by = "City",
  nrow = 1,
  ncol = 5
) +
stat_summary(aes(group = City), fun = mean, geom = "path",
              color = superbloom.10.lines) +
font("xlab", size = 18, color = "gray0") +
font("ylab", size = 18, color = "gray0") +
font("xy.text", size = 14, color = "gray20") +
```

```
rremove("ylab")
```

Arrange the panel figure

```
five.cities.leaf.herbivory.figure <- ggarrange(  
  five.cities.early.leaf.herbivory.figure,  
  five.cities.late.leaf.herbivory.figure,  
  nrow = 1,  
  ncol = 2,  
  align = "v",  
  legend = "top",  
  common.legend = TRUE  
)
```

Export the figure

```
ggsave("fig_5-five.cities_leaf_herbivory-base.pdf",  
  plot = five.cities.leaf.herbivory.figure,  
  device = "pdf",  
  path = "figures/",  
  width = 15,  
  height = 7.5,  
  units = "in",  
  dpi = 900)
```

Community Composition | Toronto

```
toronto.herbivore.abundances.wide <- toronto.herbivores %>%
  select(Population, Distance, Season) %>%
  bind_cols(toronto.community.matrix)

toronto.herbivore.abundances.long <- toronto.herbivore.abundances.wide %>%
  gather(Herbivore_Species, Measurement, Danaus:Liriomyza, factor_key = TRUE)
```

```
toronto.herbivore.abundances.figure <- ggscatter(
  data = toronto.herbivore.abundances.long,
  x = "Distance",
  y = "Measurement",
  point = FALSE,
  color = "Herbivore_Species",
  palette = cal_palette(name = "kelp1", n = 9, type = "continuous"),
  xlab = "Distance",
  ylab = "Herbivore Abundance",
  ggtheme = theme_pubr(),
  add = "reg.line",
  conf.int = TRUE
) %>%
  facet(
    facet.by = "Season",
    nrow = 1,
    ncol = 2
  ) +
  font("xlab", size = 18, color = "gray0") +
  font("ylab", size = 18, color = "gray0") +
  font("xy.text", size = 14, color = "gray20") +
  coord_cartesian(ylim = c(0, 22.5))
```

```
## Export the figure
ggsave("fig_6-toronto_herbivore_abundances-base.pdf",
  plot = toronto.herbivore.abundances.figure,
  device = "pdf",
  path = "figures/",
  width = 8,
  height = 6,
  units = "in",
  dpi = 900)
```

Community Composition | 5 Cities

```
five.cities.herbivore.abundances.wide <- five.cities.herbivores %>%
  select(City, Habitat, Season) %>%
  bind_cols(five.cities.community.matrix)

five.cities.herbivore.abundances.long.filtered <- five.cities.herbivore.abundances.wide %>%
  gather(Herbivore_Species, Measurement, Danaus:Liriomyza, factor_key = TRUE) %>%
  filter(Herbivore_Species != "Aphis")

## Toronto colour palette
toronto.continuous <- cal_palette(name = "kelp1", n = 9, type = "continuous")

## Set the 5 Cities herbivore palette to match Toronto
five.cities.herbivore.colours <- toronto.continuous[c(1:2, 5:9)]
```

```
## Early
five.cities.early.herbivore.abundances.figure <- ggerrorplot(
  data = filter(five.cities.herbivore.abundances.long.filtered, Season == "Early"),
  x = "Habitat",
  y = "Measurement",
  size = 1.5,
  width = 2,
  desc_stat = "mean_se",
  color = "Herbivore_Species",
  palette = five.cities.herbivore.colours,
  xlab = "Habitat",
  ylab = "Herbivore Abundance",
  title = "(A) Early Season Abundances",
  ggtheme = theme_pubr()
) %>%
facet(
  facet.by = "City",
  nrow = 1,
  ncol = 5
) +
font("xlab", size = 18, color = "gray0") +
font("ylab", size = 18, color = "gray0") +
font("xy.text", size = 14, color = "gray20") +
coord_cartesian(ylim = c(0, 18.5))
```

```
## Late
five.cities.late.herbivore.abundances.figure <- ggerrorplot(
  data = filter(five.cities.herbivore.abundances.long.filtered, Season == "Late"),
  x = "Habitat",
  y = "Measurement",
  size = 1.5,
  width = 2,
  desc_stat = "mean_se",
  color = "Herbivore_Species",
  palette = five.cities.herbivore.colours,
  xlab = "Habitat",
```



```

ylab = "Herbivore Abundance",
title = "(B) Late Season Abundances",
ggtheme = theme_pubr()
) %>%
facet(
  facet.by = "City",
  nrow = 1,
  ncol = 5
) +
font("xlab", size = 18, color = "gray0") +
font("ylab", size = 18, color = "gray0") +
font("xy.text", size = 14, color = "gray20") +
coord_cartesian(ylim = c(0, 31.5)) +
rremove("ylab")

```

Arrange the panel figure

```

five.cities.herbivore.abundances.figure <- ggarrange(
  five.cities.early.herbivore.abundances.figure,
  five.cities.late.herbivore.abundances.figure,
  nrow = 1,
  ncol = 2,
  align = "hv",
  legend = "top",
  common.legend = TRUE
)

```

Export the figure

```

ggsave("fig_7-five.cities_herbivore_abundances-base.pdf",
  plot = five.cities.herbivore.abundances.figure,
  device = "pdf",
  path = "figures/",
  width = 15,
  height = 10,
  units = "in",
  dpi = 900)

```

Abundance-by-Dispersal | Toronto & 5 Cities

```
toronto.abundance.by.dispersal.plot <- ggscatter(  
  data = toronto.dispersal.data,  
  x = "ln.Dispersal",  
  y = "Abundance",  
  color = "Season",  
  palette = dispersal.colours,  
  xlab = "Dispersal Distance",  
  ylab = "Abundance Response",  
  title = "(A) Toronto",  
  ggtheme = theme_pubr(),  
  legend = "right",  
  add = "reg.line",  
  conf.int = TRUE  
) +  
  font("xlab", size = 18, color = "gray0") +  
  font("ylab", size = 18, color = "gray0") +  
  font("xy.text", size = 14, color = "gray20")  
  
five.cities.abundance.by.dispersal.plot <- ggscatter(  
  data = five.cities.dispersal.data,  
  x = "ln.Dispersal",  
  y = "Abundance",  
  color = "Season",  
  palette = dispersal.colours,  
  xlab = "Dispersal Distance",  
  ylab = "Abundance Response",  
  title = "(B) 5 Cities",  
  ggtheme = theme_pubr(),  
  legend = "right",  
  add = "reg.line",  
  conf.int = TRUE  
) +  
  font("xlab", size = 18, color = "gray0") +  
  font("ylab", size = 18, color = "gray0") +  
  font("xy.text", size = 14, color = "gray20") +  
  rremove("ylab")
```

Arrange the panel figure

```
abundance.by.dispersal.figure <- ggarrange(  
  toronto.abundance.by.dispersal.plot,  
  five.cities.abundance.by.dispersal.plot,  
  nrow = 1,  
  ncol = 2,  
  align = "v",  
  legend = "top",  
  common.legend = TRUE  
)
```

Export the figure

```
ggsave("fig_S4-abundance_by_dispersal-base.pdf",
```

```
plot = abundance.by.dispersal.figure,  
device = "pdf",  
path = "figures/",  
width = 8,  
height = 6,  
units = "in",  
dpi = 900)
```

R Session Information

Table 1: Packages required for data management and figure creation.

Package	Loaded Version	Date
calecopal	0.1.0	2021-05-24
dplyr	1.0.8	2022-02-08
forcats	0.5.1	2021-01-27
ggmap	3.0.0	2019-02-05
ggplot2	3.3.5	2021-06-25
ggpubr	0.4.0	2020-06-27
gridExtra	2.3	2017-09-09
kableExtra	1.3.4	2021-02-20
knitr	1.38	2022-03-25
mapdata	2.3.0	2018-03-30
maps	3.4.0	2021-09-25
maptools	1.1-3	2022-03-08
purrr	0.3.4	2020-04-17
readr	2.1.2	2022-01-30
scales	1.1.1	2020-05-11
sp	1.4-6	2021-11-14
stringr	1.4.0	2019-02-10
tibble	3.1.6	2021-11-07
tidyr	1.2.0	2022-02-01
tidyverse	1.3.1	2021-04-15