Urbanization influences communities of milkweed-specialist herbivorous insects
ON_herb Figures

Lindsay S. Miles   Vanessa J. Nahn   David Murray-Stoker   Marc T. J. Johnson

Contents

```r
## 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

```r
## 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

```r
## 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
```

```r
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",
```

```r
    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",
```

```r
                                  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",
```

```r
        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") +
    rremove("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

```r
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")
```

```r
## 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") +
```

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

```r
## 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
)
```

```r
## 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

```r
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)
```

```r
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))
```

```r
## 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 == "Rhyssomatus" | Herbivore_Species == "Liriomyza")

## 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(2, 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 = 7.5,
            units = "in",
            dpi = 900)
```

Abundance-by-Dispersal | Toronto & 5 Cities

```r
toronto.abundance.by.dispersal.plot <- ggscatter(
    data = toronto.dispersal.data,
    x = "ln.Dispersal",
    y = "Abundance",
    color = "Season",
    palette = dispersal.colours,
    xlab = "ln(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 = "ln(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