Grasshoppers as important indicators of changes in climate and land use

César R Nufio
Dept of Ecology & Evolutionary Biology, CU Museum
Grasshoppers as important indicators of changes in climate and land use

1. Grasshoppers in grassland ecosystems

2. Grasshoppers and climate change
   - Gordon Alexander’s 1958-1960 grasshopper survey along an elevational gradient

3. Urban fragmentation - the importance of Kingfisher Point

http://www.ndsu.nodak.edu/entomology/hopper/orthoptera_home.htm
Grasshoppers

Are important components of grassland ecosystems
- as herbivores
Grasshoppers

Are important components of grassland ecosystems
- as herbivores


Densities of 25 grasshoppers per square meter ...and at that density there are approximately 412 tons of grasshoppers ...the tonnage of grasshoppers is about 120 percent the tonnage of big herbivorous mammals.

on the National Bison Range, Montana 18,500 acres
Grasshoppers are important components of grassland ecosystems on the African Savanna - as herbivores.

TABLE 3. Grass consumption by grasshoppers in African savannas, compared with consumption by mammalian herbivores. The Serengeti supports large populations of ungulates, and also herbivorous rodents. Nyilsvley supports domestic cattle as well as native ungulates.

<table>
<thead>
<tr>
<th></th>
<th>Serengeti, Tanzania (Sinclair, 1975)</th>
<th>Nyilsvley, South Africa (Gandar, 1982a, b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Long grassland</td>
<td>Short grassland</td>
</tr>
<tr>
<td>Biomass consumed (kg ha⁻¹ yr⁻¹)</td>
<td>456</td>
<td>194</td>
</tr>
<tr>
<td>Per cent total herbivore consumption</td>
<td>28</td>
<td>11</td>
</tr>
</tbody>
</table>
Grasshoppers

Are important components of grassland ecosystems
- as herbivores - food resources

Grasshoppers

Are important components of grassland ecosystems
- as herbivores  - food resources

Grasshoppers

Are important components of grassland ecosystems as herbivores - food resources

Global News Blog

Uganda's booming grasshopper industry leaps over tradition

Ugandan tradition dictates that only women and children catch grasshoppers, but high profit margins have brought men into the industry, too.

A vendor sells fresh grasshoppers in Kampala, Uganda.
Wang Ying/Newscom/file
Grasshoppers

Are important components of grassland ecosystems

- as herbivores
- as food resources

Grasshoppers, China

Grasshoppers

Are important components of grassland ecosystems
- as herbivores  - as nutrient cyclers  - food resources
- relatively diverse  (133 species in CO; 72 FR), vary in a variety of life history traits

Diapause
Diet
Size
Winged or wingless
Relative abundance
Time of the season
Spatial distribution

http://www.ndsu.nodak.edu/entomology/hopper/orthoptera_home.htm
Grasshoppers as important indicators of changes in climate and land use

1. Grasshoppers in grassland ecosystems

2. Grasshoppers and climate change

   - Gordon Alexander’s 1958-1960 grasshopper survey along an elevational gradient

3. Urban fragmentation - the importance of Kingfisher Point

http://www.ndsu.nodak.edu/entomology/hopper/orthoptera_home.htm
Climate Change

Over the last century, global temperatures have increased by $0.74 \pm 0.18 \, ^\circ C$
$1.30 \pm 0.32 \, ^\circ F$

(IPCC 2007)
Climate Change

Over the last century, global temperatures have increased by $0.74 \pm 0.18 \, \text{C}^0$
$1.30 \pm 0.32 \, \text{F}^0$

(IPCC 2007)

Deviations from 1961-1990 average

The hottest 10 years on record in order

2010
2005
1998
2003
2002
2009
2006
2007
2004
2001

2001-2010 10 of the 12 hottest years in the last 130
Surface temperature Anomaly (°C)
Warming temperatures may affect organisms in a variety of ways

i. Phenology (timing of annual biological events)

ii.

iii.
Phenology: The timing of annual biological events

For plants: first flush of leaves, first flowering or fruiting dates, when leaves turn in the fall

For animals: breaking of hibernation or diapause, egg-laying dates, timing of migration, when different life stages are reached
Warming temperatures may affect organisms in a variety of ways

i. Phenology  (timing of annual biological events)

ii. Distributions

iii. 
Warming temperatures may affect organisms in a variety of ways

i. Phenology (timing of annual biological events)

ii. Distributions

iii. Local Extinctions
For Insects, plants and other ectotherms, development is related to temperature

Trudgill et al. 2005
For Insects, plants and other ectotherms, development is related to temperature.

Trudgill et al. 2005
For Insects, plants and other ectotherms, development is related to temperature.

- Base temp (12°C)
- Upper threshold temp (38°C)

Temperature (°C)

Developmental rate

No development

Cooler → Warmer

Trudgill et al. 2005
For Insects, plants and other ectotherms, development is related to temperature.

Trudgill et al. 2005
Grasshoppers as important indicators of changes in climate and land use

1. Grasshoppers in grassland ecosystems

2. Grasshoppers and climate change
   - Gordon Alexander’s 1958-1960 grasshopper survey along an elevational gradient

3. Urban fragmentation - the importance of Kingfisher Point

http://www.ndsu.nodak.edu/entomology/hopper/orthoptera_home.htm
Gordon Alexander

Faculty member in CU’s Biology department (1939 - 1966)

Interested in:

The biology of organisms living along elevational gradients

http://alexander.colorado.edu
1958-1960  **Gordon Alexander survey**

NSF supported project  ($25,000)

**Goal:** document species, distributions & phenology of local grasshoppers
1958-1960 - Surveyed grasshoppers at 8 main sites (weekly basis, March-Sept)

- Valmont Butte to weather station C1 (foothills to subalpine gradient)

- 1,615 m (5,300 ft) to 3,048 m (10,000 ft)
2.5 miles south of Boulder
2.5 miles south of Boulder

Fairview High School
Each survey event reflected the developmental stages of grasshoppers within each community.
1958-1960  Gordon Alexander Grasshopper Survey

Alexander kept extensive field notes for all weekly collecting events at each site

- **species present**
- **developmental stages**

---

**Collection #14.**

June 24, 1958.

Collectors: The Acridian Research Group, Univ. of Colo.
(Brad Alexander, John Hilliard, Don Van Horn, Kathy Alexander)

Station I-4. Elevation 7000'. Collected from about 11:20-11:45 am.
(This is weather station of University of Colorado Alpine Research Group A-1)
Weather: cool, overcast, threatening rain.
Slope: not measured...about 15-20°. Exposure: South facing mixed vegetation meadow.
More herbaceous plants than grasses. Dominant trees: Ponderosa pine.
Plants identified (tentatively):

2. Opuntia sp. Prickly pear.
3. Eriogonum umbellatum. (Evidence indicates a feeding relationship between Melanoplus dodegi inculatus and this plant. Trichomes (very dense and cottony on the underside of the leaves of this plant) of Eriogonum umbellatum resemble very closely fibrous trichomes found in the crops of Melanoplus dodegi specimens collected at this locality.
4. Potentilla hirsuta L. Woolly Cinquefoil.
5. Potentilla viscosa Nutt. Sticky Cinquefoil.
6. Bromus japonicus Thub. (or more probably Bromus tectorum L. Downy chess)
8. Artemisia ludoviciana Nutt. (fairly common on slope.)
10. Phacelia heterophylla Pursh.

---

**Total Specimens Collected:**

**Acrideridae:**

- Eritettix simplex tricarinatus 10 male; 5 female adult.
- Aeropedellus clavatus 1 (5) female.

**Oedipodinae:**

- Xanthippus corollipes 1 male adult.
- Arphia conspersa 3 male adult; 2 female adult. (all with yellow wing discs)
- Trimerotropis p. palloulipes 1 male adult.
- Rust colored Oedipodine with black and white banded hind femur. 1 (2); 1 (3); 1 (4).
- Oedipodine with yellow hind tibia, grey colored, 1 notch in median carina. 3 (4).

**Ctenothoidinae:**

- Melanoplus confusivus 1 male adult; 3 female adult.
- Melanoplus dodegi inculatus 10 male adult; 6 female adult; 3 female & 4 male (5);
- Melanoplus occidentalis occidentalis (Thomas) 1 male adult.
- Melanoplus mexicanus 5 (4) males; 1 (4) females; 2 (3) males; 1 (2) male, 2 (1)
- Melanoplus bivittatus 1 (4) male.
- Esperotettix viridis 1 (3) male. (fairly common, a group of specimens brought in alive; about 3rd instar.)
Grasshoppers have 5 developmental stages before they become adults.
1958-1960 Gordon Alexander survey

- Processed 65,000 grasshoppers, 73 species
- 13,500 pinned and labeled
1958-1960 **Gordon Alexander survey**

- 4 sites adjacent to weather stations

- A1- D1 Stations set up in the early 1950’s (currently maintained by Niwot LTER)

**Chautauqua Mesa**

Dr. John Marr
Founded INSTAAR
Mnt Research station
How has climate changed along Alexander's elevational gradient?

Elevation-dependent temperature trends in the Rocky Mountain Front Range over a 54-year and a 20-year record --- Chris McGuire et al.
How has climate changed along Alexander's elevational gradient?

Mean temperature (°C) March-August

- Chautauqua
- A1
- B1
- C1

- ** 1955-1964
- 1999-2008

Foothills  Subalpine
Given no significant change in temp, has the time to reach adulthood changed?

<table>
<thead>
<tr>
<th>Station</th>
<th>Species</th>
<th>Earliest ordinal date to adulthood 1959-1960</th>
<th>Change in timing to adulthood 2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chautauqua Mesa</td>
<td><em>Aeropedullus clavatus</em></td>
<td>152</td>
<td>........................................</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Melanoplus confucus</em></td>
<td>155</td>
<td>........................................</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. sanguinipes</em></td>
<td>176</td>
<td>........................................</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. bivittatus</em></td>
<td>181</td>
<td>........................................</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Hesperotettix viridis</em></td>
<td>186</td>
<td>........................................</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. dawsoni</em></td>
<td>186</td>
<td>........................................</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Given no significant change in temp, has the time to reach adulthood changed?

<table>
<thead>
<tr>
<th>Station</th>
<th>Species</th>
<th>Earliest ordinal date to adulthood 1959-1960</th>
<th>Change in timing to adulthood 2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chautauqua Mesa</td>
<td><em>Aeropedullus clavatus</em></td>
<td>152</td>
<td>--</td>
<td>-11</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Melanoplus confucus</em></td>
<td>155</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. sanguinipes</em></td>
<td>176</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. bivittatus</em></td>
<td>181</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Hesperotettix viridis</em></td>
<td>186</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. dawsoni</em></td>
<td>186</td>
<td>--</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2007

1/6 earlier

2008

0/6 earlier
Given 2 C⁰ (3.6 F⁰) change in temp has the time to reach adulthood changed?

<table>
<thead>
<tr>
<th>Station</th>
<th>Species</th>
<th>Earliest ordinal date to adulthood 1959-1960</th>
<th>Change in timing to adulthood 2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station B1</td>
<td><em>Aeropedellus clavatus</em></td>
<td>172</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Melanoplus dodgei</em></td>
<td>172</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Cannula pellucida</em></td>
<td>202</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Circotettix rabula</em></td>
<td>207</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. dawsoni</em></td>
<td>215</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Chloelitis abdominalis</em></td>
<td>216</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. packardi</em></td>
<td>216</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Given 2 C\( ^0 \) (3.6 F\( ^0 \)) change in temp has the time to reach adulthood changed?

<table>
<thead>
<tr>
<th>Station</th>
<th>Species</th>
<th>Earliest ordinal date to adulthood 1959-1960</th>
<th>Change in timing to adulthood 2006</th>
<th>Change in timing to adulthood 2007</th>
<th>Change in timing to adulthood 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station B1</td>
<td><em>Aeropedellus clavatus</em></td>
<td>172</td>
<td>-13</td>
<td>-17</td>
<td>-10</td>
</tr>
<tr>
<td></td>
<td><em>Melanoplus dodgei</em></td>
<td>172</td>
<td>-13</td>
<td>-17</td>
<td>-10</td>
</tr>
<tr>
<td></td>
<td><em>Camnula pellucida</em></td>
<td>202</td>
<td>-14</td>
<td>-11</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Cercotettix rabula</em></td>
<td>207</td>
<td>-19</td>
<td>-10</td>
<td>-16</td>
</tr>
<tr>
<td></td>
<td><em>M. dawsoni</em></td>
<td>215</td>
<td>-27</td>
<td>-18</td>
<td>-8</td>
</tr>
<tr>
<td></td>
<td><em>Chloaletis abdominalis</em></td>
<td>216</td>
<td>-21</td>
<td>-19</td>
<td>-18</td>
</tr>
<tr>
<td></td>
<td><em>M. packardi</em></td>
<td>216</td>
<td>-36</td>
<td>-26</td>
<td>-18</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>-20 d</td>
<td>-16 d</td>
<td>-13 d</td>
</tr>
</tbody>
</table>

**2006**
7/7 earlier

**2007**
6/7 earlier

**2008**
7/7 earlier
Station B1 - 2591m (8500ft)

Grasshoppers in 1959

Grasshoppers in 2006
Using a community level approach at four collecting areas with detailed weather data

Conclusions

Warming is elevation dependent
mid- high elevations warmed more than lower elevations
Using a community level approach at four collecting areas with detailed weather data

Conclusions

Warming is elevation dependent
mid- high elevations warmed more than lower elevations

Higher sites showed greater community level responses

Chautauqua Mesa 1/6 earlier

Station B1 7/7 earlier
Using a community level approach at four collecting areas with detailed weather data

Conclusions

Warming is elevation dependent
mid- high elevations warmed more than lower elevations

Higher sites showed greater community level responses

Chautauqua Mesa  1/6 earlier
Station B1  7/7 earlier

Species that become adults later in the season (at B1) are more strongly affected by warming

Most studies show that early species display greatest advancement
- flowering plants, diatoms, dragonflies  (Fitter & Fitter 2002, Hassall 2007, Adrian et al 2006)
Grasshoppers as important indicators of changes in climate and land use

1. Grasshoppers in grassland ecosystems

2. Grasshoppers and climate change
   - Gordon Alexander’s 1958-1960 grasshopper survey along an elevational gradient

3. Urban fragmentation - the importance of Kingfisher Point

http://www.ndsu.nodak.edu/entomology/hopper/orthoptera_home.htm
The history of habitat reduction and fragmentation in a Wisconsin forest

Fragmented areas become smaller & farther away from other fragments.
The history of habitat reduction and fragmentation in a Wisconsin forest

Fragmented areas become smaller & farther away from other fragments
The history of habitat reduction and fragmentation in a Wisconsin forest

Fragmented areas become smaller & farther away from other fragments.
The history of habitat reduction and fragmentation in a Wisconsin forest

Fragmented areas become smaller & farther away from other fragments.
Fragmented areas become smaller & farther away from other fragments.
Grasshopper Survey Methods

Sampled 13 fragments (0.85-37.31 ha) Boulder, Denver Fort Collins areas

<table>
<thead>
<tr>
<th>Fragment</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manor Care</td>
<td>0.85</td>
</tr>
<tr>
<td>Loveland</td>
<td>1.76</td>
</tr>
<tr>
<td>Twin Lakes</td>
<td>1.84</td>
</tr>
<tr>
<td>Red Fox</td>
<td>3.94</td>
</tr>
<tr>
<td>Niwot Estate</td>
<td>4.92</td>
</tr>
<tr>
<td>Forest Dump</td>
<td>6.04</td>
</tr>
<tr>
<td>Ute Trail</td>
<td>6.78</td>
</tr>
<tr>
<td>Tamarisk</td>
<td>10.3</td>
</tr>
<tr>
<td>Holly</td>
<td>10.94</td>
</tr>
<tr>
<td>Ravines</td>
<td>11.04</td>
</tr>
<tr>
<td>Willow Spring</td>
<td>21.66</td>
</tr>
<tr>
<td>Kingfisher Point</td>
<td>32.43</td>
</tr>
<tr>
<td>Crown Hill Park</td>
<td>37.31</td>
</tr>
</tbody>
</table>
**Grasshopper Survey Methods**

Sampled 13 fragments (0.85-37.31 ha) Boulder, Denver Fort Collins areas

<table>
<thead>
<tr>
<th>Fragment</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manor Care</td>
<td>0.85</td>
</tr>
<tr>
<td>Loveland</td>
<td>1.76</td>
</tr>
<tr>
<td>Twin Lakes</td>
<td>1.84</td>
</tr>
<tr>
<td>Red Fox</td>
<td>3.94</td>
</tr>
<tr>
<td>Niwot Estate</td>
<td>4.92</td>
</tr>
<tr>
<td>Forest Dump</td>
<td>6.04</td>
</tr>
<tr>
<td>Ute Trail</td>
<td>6.78</td>
</tr>
<tr>
<td>Tamarisk</td>
<td>10.3</td>
</tr>
<tr>
<td>Holly</td>
<td>10.94</td>
</tr>
<tr>
<td>Ravines</td>
<td>11.04</td>
</tr>
<tr>
<td>Willow Spring</td>
<td>21.66</td>
</tr>
<tr>
<td>Kingfisher Point</td>
<td>32.43</td>
</tr>
<tr>
<td>Crown Hill Park</td>
<td>37.31</td>
</tr>
</tbody>
</table>

Twin Lakes & Red Fox
Grasshopper diversity and fragment size

Found a total of 38 unique species

On average there were 16 species at a site

At Kingfisher Point – 32 species

(But there may be more)
Grasshopper diversity and fragment size

Hesperotettix speciousa

“Western green grasshopper”
Grasshopper diversity and fragment size

Number of species vs. Hectares

Graph showing the relationship between grasshopper diversity and fragment size in hectares.
Why are there fewer species at smaller sites?

1. *Habitat diversity*

2. *Rarity*
Why are there fewer species at smaller sites?

1. Habitat diversity
1. Habitat diversity
1. Habitat diversity

Kingfisher Point
Why are there fewer species at smaller sites?

1. Habitat diversity

2. Rarity

- Rare
- Common
Why are there fewer species at smaller sites?

1. Habitat diversity

2. Rarity
Why are there fewer species at smaller sites?

1. *Habitat diversity*

2. *Rarity*

Many of the species that are unique to the largest sites are rare/uncommon

Small sites full of very common species
Kingfisher point is important for a variety of animal

- Preserves habitat and uncommon/rare species

Fort Collins Natural Areas Program offices from Kingfisher Point Natural Area, Karl Manderbach
Grasshopper behavior

Measure:
Ambient temp
Ground temp
Body temp