The Current State of Arthropod Biodiversity Data: Addressing Impacts of Global Change

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The Current State of Arthropod Biodiversity Data: Addressing Impacts of Global Change

- Focus on North America – United States > Canada
- How many species can we model future distributions under climate change? (n>30)
- Museum occurrence records:
  - Holdings in NA museums
  - Biogeography
  - Collection Timeline
- Major taxonomic and functional groups
- Linking trophic connections
Race Against Time: Key Observations

- Arthropods comprise ~70% of described species, only 15% of climate impact studies
- ~15% of arthropod species have been described, 70% for North America (?)
- Less than 10% of arthropod species have “enough” occurrence data
- 600,000 million specimens worldwide, <50,000,000 digitized (8%)
- Cannot predict climate change impacts without knowing existing species distributions
- Arthropod occurrence data resides primarily in museum collections
Arthropods Dominate Biodiversity ~70%

Really: Insects Dominate Biodiversity ~63%

Or at least Binominal Biodiversity

* From Evolution of Insects
North American Arthropod Functional Diversity: Major Players

Seven Major Terrestrial Arthropod Orders

**Economic & Health Impacts**
- Pests (Herbivores & Parasites)

**Ecosystem Services**
- Parasitoids & Predators
- Pollinators
- Herbivores (Biocontrol & Food)
- Ants*
- Decomposers*

*Not showing data for this talk
Understanding Climate Change Impacts on Arthropods
Ecological Niche Modeling, Species Distribution **Modeling**

**Present Goals**
- Document Present Distributions
- Promote Data Acquisition

**Near-Future Goals**
- Predict Biodiversity
- Predict Future Species Distributions

**Way in the Future Goals**
- Understand Mechanisms
- Model Cross-Trophic Interactions
Predicting Impacts of Climate Change on Species Distributions

- 30-100 occurrence localities
- Distributed over entire range

**BIOMOD2+ Modeling Workflow**

**Occurrence Records**
- rGBIF, SEINET
- FIA/Landfire (1/0)

**Environmental Layers**
- Climate (WorldClim → BioClim)
- Soils (gSSURGO)
- DEM-based layers (Landfire)
- Habitat, Disturbance, etc. (Landfire)

**Environmental Processing**
- Transformations and projections
- Adjusting resolution

**BIOMOD2 Modeling**
- Algorithms, # Runs, Data split
- Evaluate individual algorithms
- Variable importance output
- Generate ensemble model
- Predicted suitable habitat map

**Future/Past Distributions**
- Future: Ensemble map of multiple GCMs
- Migration simulations (MigClim)
- Past: LIG (~130 kya), LGM (~21 kya) and mid-holocene (~6 kya) from WorldClim (~5 km)
Field-observable arthropod taxa
- Dragonflies some damselflies
- Butterflies
- Ants
- Grasshoppers
- Mantids
- Crickets
- Cockroaches
- Earwigs
- Vespid Wasps

Projects that use observations
- Odonata Central
- Butterflies & Moths of NA
- BugGuide
- Discoverlife (Bee Hunt)
- Life on Loosestrife
- Cricket Crawl
- Lost Ladybug
- Great Sunflower Project

# of NA arthropod species that can be observed in field
- 3,001 species
- 6,000 aquatic & miscellaneous species??
- 9,000 total observable species

95,000 total “unobservable” species

- Museums currently hold the vast majority of arthropod occurrence data!!
- How many arthropod species are observable in the field?
The Data

- Museum Occurrence Records for United States & Canada
- Three sources of data

Southwest Collections of Arthropods TCN

+ Tri-Trophic TCN

= GBIF

(500k) + (900k) + (3.2 million) = 4,606,160
Methods

The “Seltmann model 865B” Biodiversity Cluster Array

1. Compile raw data
2. Clean data
3. Format data
4. Compile & run scripts
Museum Occurrence Records for United States & Canada

2,166 Families
20,153 Genera
80,161 Species (105,000 [?] total)

4,606,160 Specimen Records
3,7331,257 Georeferenced Records (81%)
2,803,956 Identified to Species (77%)
North American Arthropod Collections
(USA-Canada-Mexico)

Key Estimates

Current Holdings
- 237 million specimens accounted for
- >17 million not accounted for
- 254 million Total specimens in NA collections
- 85 million Total North American specimens (?)
- 6 million digitized North American specimens (?)
North American Arthropod Collections
(USA-Canada-Mexico)

Can we catch up?

Key Estimates

Current Holdings
237 million specimens accounted for
>17 million not accounted for
254 million Total specimens in NA collections
85 million Total North American specimens (?)

Annual Additions
3.8 million total new specimens per year
1.2 million new North American specimens per year
Can we catch up?

- Total specimens in NA collections
- 5-Fold increase in rate of digitization
- NA specimens in NA collections
- Current rate of digitization
Biogeography of NA Arthropod Collections
692,749 Species Records (Georeferenced)
Timeline of Arthropod Collecting

4.2 million total records
1,526 records before Columbus
637 records in future

1.6 million records
Pre-Climate Change

Year Collected
1840 1860 1880 1900 1920 1940 1960 1980 2000

#Specimens Digitized (Millions)
0 20 40 60 80 100 120

2011 2012 2013
Research Ready Data (identified to species & georeferenced)

52,604 species

- 8,871 species (11%)
Taxonomic Distribution: Databased Species

Number of Species

- Araneae
- Orthoptera
- Hemiptera
- Coleoptera
- Hymenoptera
- Diptera
- Lepidoptera

# Species in NA  # Species in database
Vector pests
Aquatics
Herbivores
Pollinators
Predators
Parasitoids

Ecological Distribution: Databased Species

# of Species

Vector pests Aquatics Herbivores Pollinators Predators Parasitoids

# Species in NA # Species in database
Ecological Distribution: Expected vs. Observed Records
Status of *Research-Ready* Arthropod Biodiversity Data

1. Fraction of specimens digitized, but enough to model for climate change impacts.

2. Exponentially Increase current rate of digitization to fully utilize existing specimen data.

3. Biogeography of specimen records suggests significant bias.

4. Historical data indicate a enough taxa can be used to test for climate change responses NOW.

5. Taxonomic breadth of data generally good (except Diptera).

6. Ecological breadth of data generally good (except predators & parasitoids).
Stacked Species Distribution Models

• Can assess overlap among species
• Predicted community “types”
• Examine Biotic Interactions
Assessment of Trophic Network Data

1. Rigorous data-filtering framework

2. High confidence in < 20% of recorded associations
Interim Conclusions

Lots to do

Lots to work with

Take Your Pick

TCN Collaboration

Really
11% Full
Next Steps

• Extend analyses to Mexico and Central America.

• Compare with other continents and oceans as well as other phyla in North America.

• Create a website that provides near real time statistics to identify gaps and advertise research-ready data.

• Promote novel digitization-based opportunities for expert contributions (floras, faunas, “e-revisions”)

Tri-Trophic Thematic Collection Network

SCAN Southwest Collections of Arthropods Network
Conclusions: A few suggestions

Promote interoperability of user-friendly databases & software (Symbiota, Arthropod Easy, Arctos [GBIF], CalBug?)

Push for technological advances (InvertNet imaging [100’s to >1000 specimens per image])

Crowd-sourcing (Notes from Nature)

Increase # of observable species (DiscoverLife)

Extend beyond political boundaries (SpeciesLink, GBIF)
Timeline Biogeography of NA Arthropod Collections
692,749 Species Records (geo-referenced)
North American Arthropod Collections
(USA-Canada-Mexico)

Canada

USA

Mexico
Specific ways museums can address climate change impacts on Arthropods

1. Provide occurrence records from museum specimens

2. Provide expertise
   A. Monitoring Programs
   B. Observational Inventories
   C. Taxonomic Revisions
   D. Identification Services through Loans
   E. Training Taxonomists and Parataxonomists