Taxonomic concept resolution for voucher-based biodiversity information platforms

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Symposium - Specimens Full Circle: Collection to Digitization to Data Use

30th Annual Meeting, Society for the Preservation of Natural History Collections

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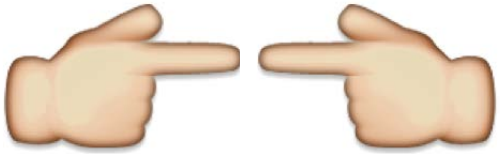
@ http://www.slideshare.net/taxonbytes/franz-2015-spnhc-taxonomic-concept-resolution-for-voucherbased-biodiversity-information-platforms

Taxonomic concept resolution





for voucher-based biodiversity




information platforms



This talk is about..

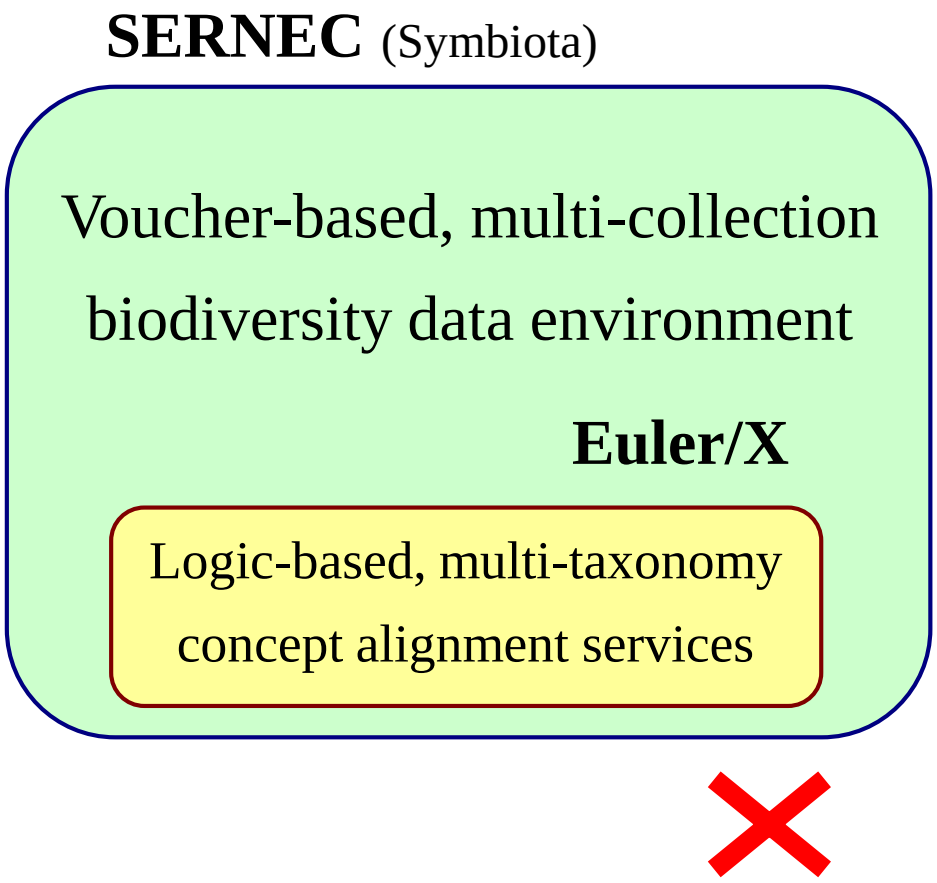
SERNEC (Symbiota)

Voucher-based, multi-collection biodiversity data environment

Euler/X

Logic-based, multi-taxonomy concept alignment services

This talk is about..



Introducing the SERNEC portal (sustained by Symbiota)

sernecportal.org/portal/

SERNEC
Southeast Regional Network of Expertise and Collections

Home | Search Collections | Map Search | State Floras | Dynamic Tools | Images | Welcome Nico! My Profile Logout Sitemap

Welcome to SERNEC

Herbaria are not simply repositories of plant specimens, they are repositories of a tremendous amount of information. Current technologies provide an opportunity to access this information at an unprecedented scale. The real power of herbaria as research tools can be fully realized when both large and small collections within a broad geographic region are electronically available and searchable.

SERNEC (SouthEast Regional Network of Expertise and Collections) is designed to facilitate this process, by building partnerships, encouraging the utilization of the collective expertise of the network, and assisting herbaria in providing information to the public.

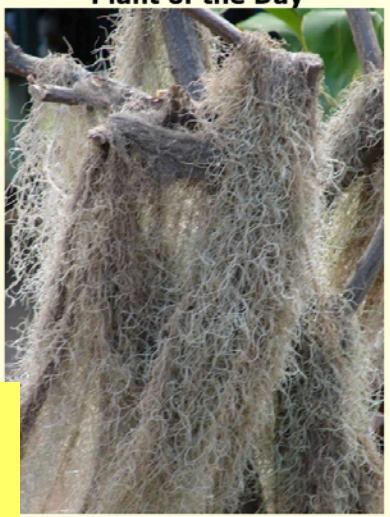
SERNEC is 1) networking the 230 herbaria in 14 states in southeastern North America, 2) developing a strategy for advancing each state's ongoing databasing effort, and 3) working to publish online botanical resources that will be available to scientists, land managers, state and federal agencies, educators and the general public. These data will provide a greater understanding of one of the most botanically diverse regions of the earth and will lead to better research, better management planning and a more well-informed public.

Development of a searchable collective database at a regional scale will provide a powerful research tool, and by combining 150 years of botanical information housed in herbaria in the Southeast with models of past plant migrations and current ecological parameters, we can revolutionize studies in biodiversity, evolution, ecology and systematics. We are also working to link our efforts with those of other regional herbarium groups through the US Virtual Herbarium and with the national biodiversity informatics effort, iDigBio.

Search Collections

General Data Usage Policy

Plant of the Day



What is this plant?
Click here to test your knowledge

sernecportal.org

Holdings, May 2015

- 27 herbarium collections
- 607,300 occurrences
- 17,300 species-level units

This project made

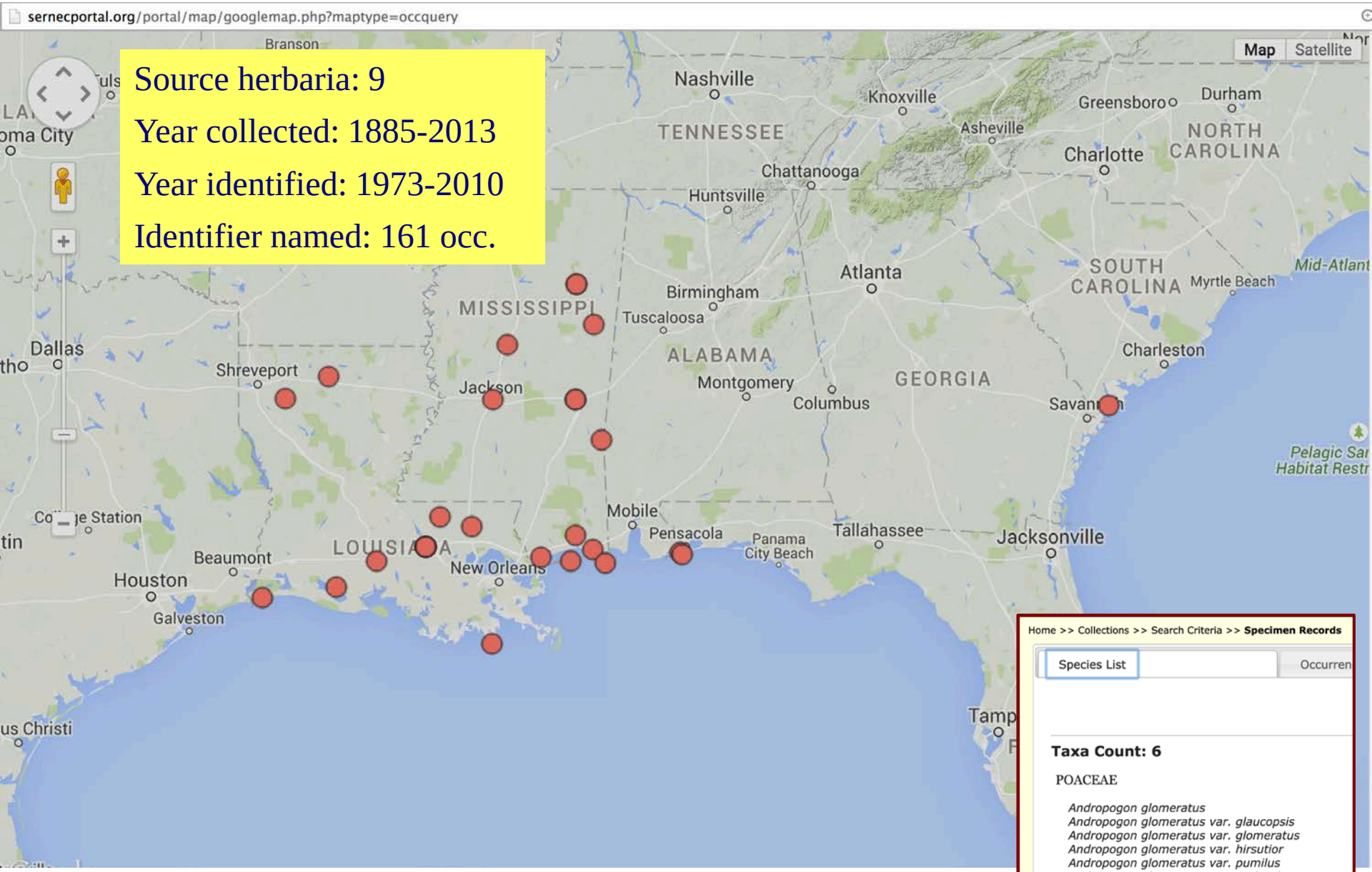
Andropogon glomeratus

- Bushy bluestem

Ok. SERNEC search!

Photo by Max Licher (ASU Herbarium); Cottonwood, Arizona.
http://swbiodiversity.org/seinet/imagelib/imgdetails.php?imgid=431755

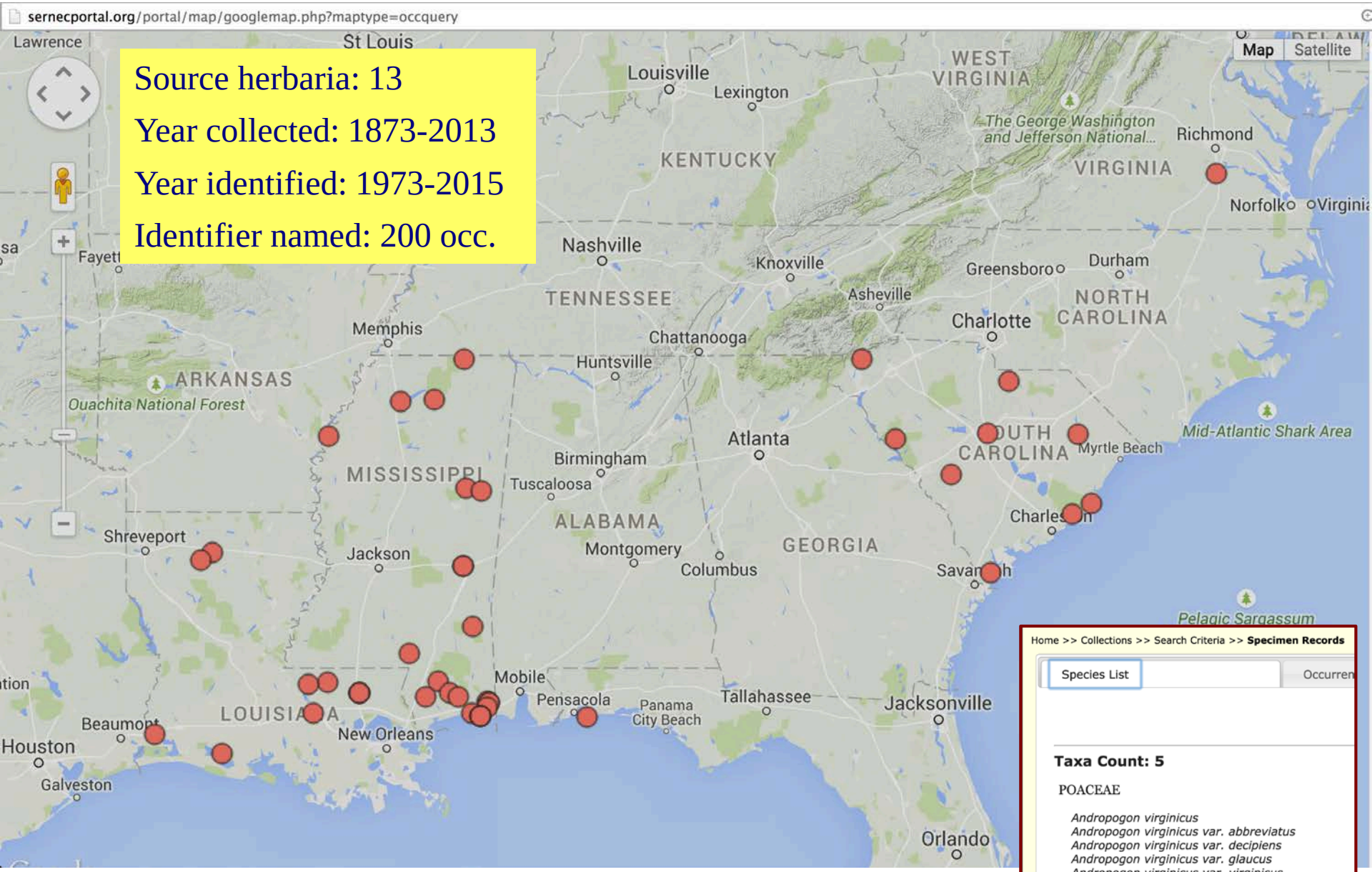
Search for "*Andropogon glomeratus*" returns **255** occurrences[1]



[1] SERNEC portal, May 15, 2015; with synonyms, raw taxonomy.

Isn't that one similar to ***virginicus?***

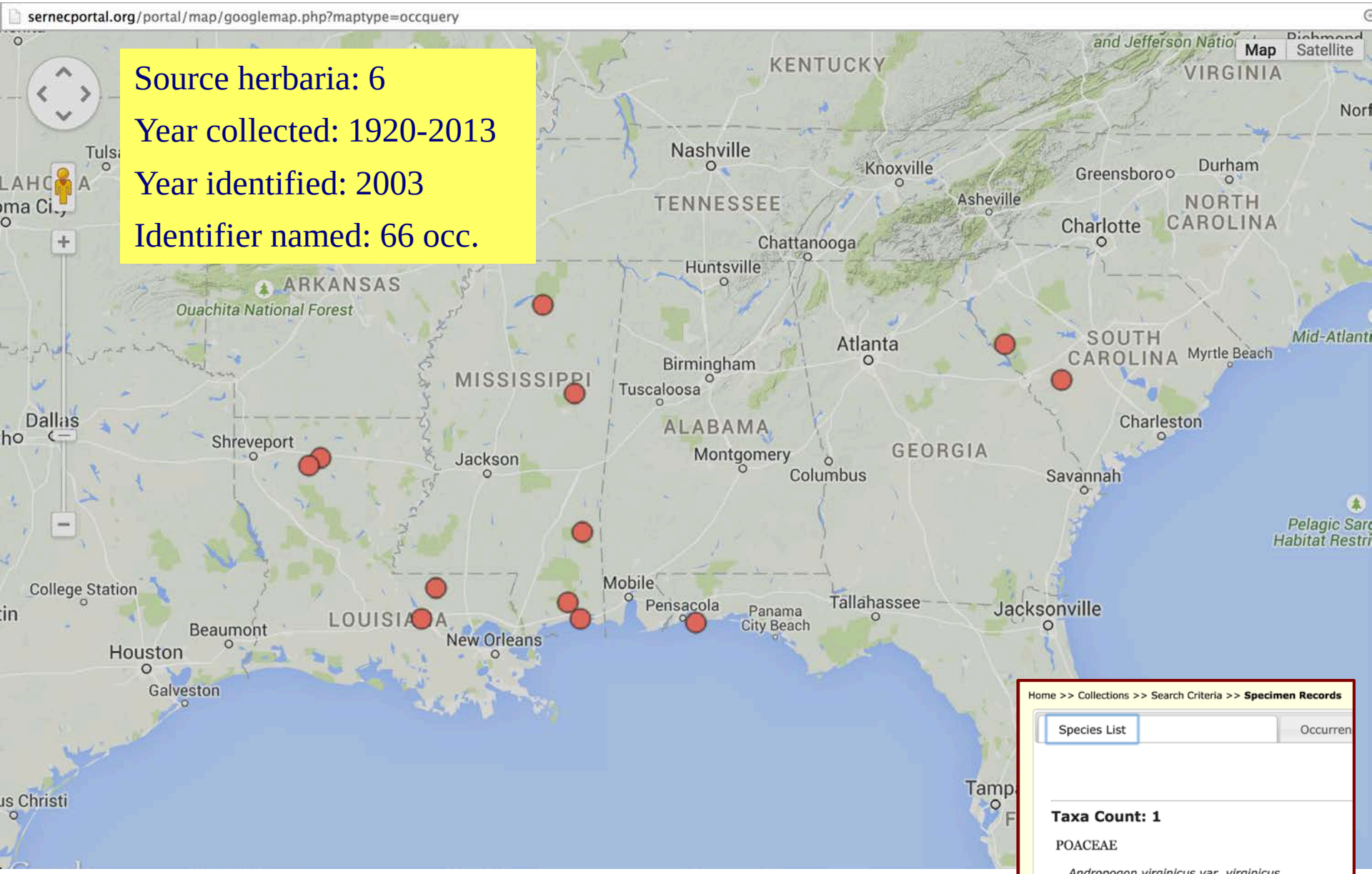
Search for "*Andropogon virginicus*" returns **442** occurrences[1]



[1] SERNEC portal, May 15, 2015; with synonyms, raw taxonomy.

What about the nominal **subspecies?**

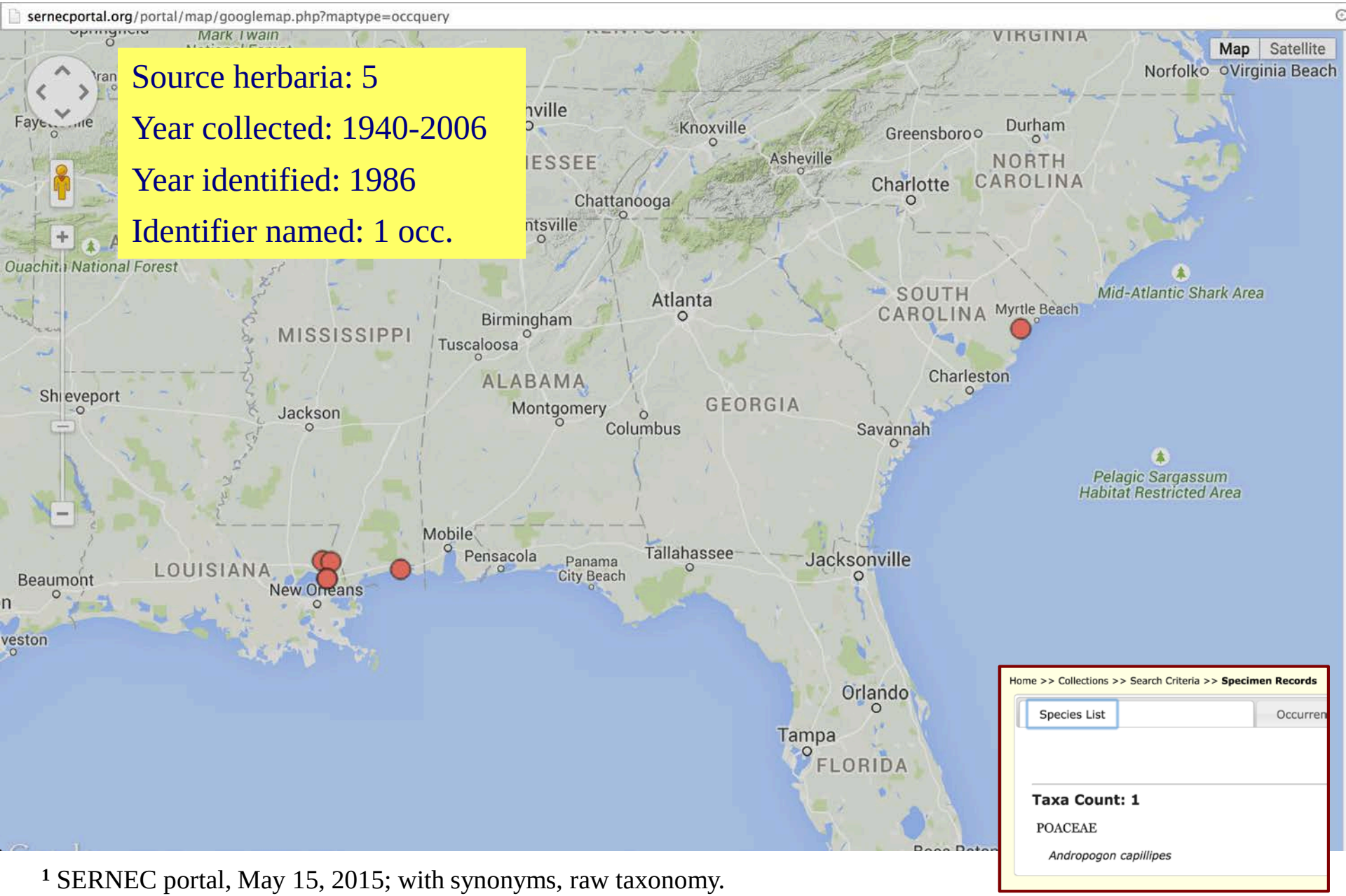
Search for "*A. virginicus* var. *virginicus*" returns **101** occurrences[1]



[1] SERNEC portal, May 15, 2015; with synonyms, raw taxonomy.

I believe some Floras recognize ***capillipes.***

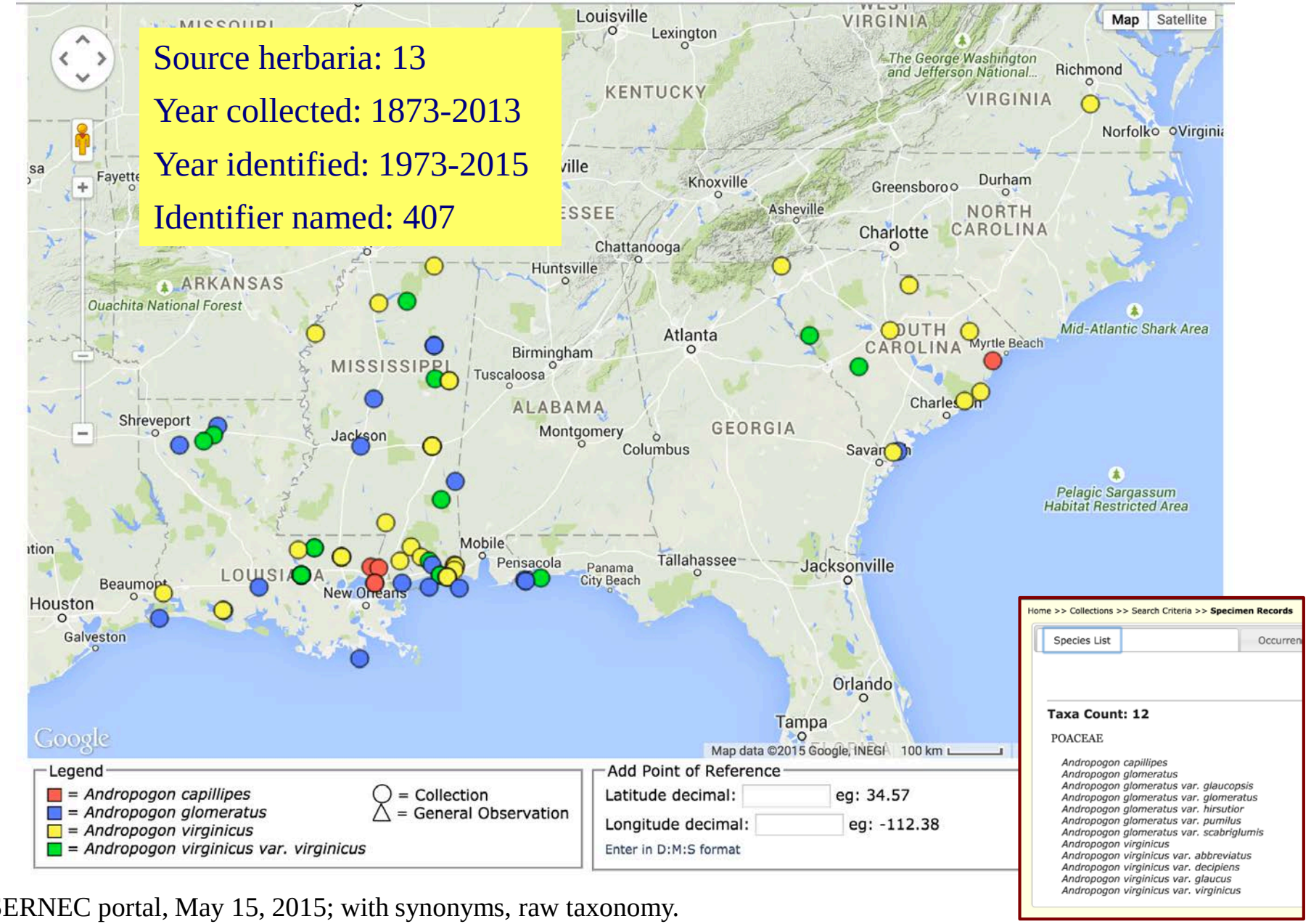
Search for "*Andropogon capillipes*" returns **72** occurrences[1]



[1] SERNEC portal, May 15, 2015; with synonyms, raw taxonomy.

Show **four-in-one** occurrence-based maps.

Combined four-in-one search returns **769** occurrences[1]



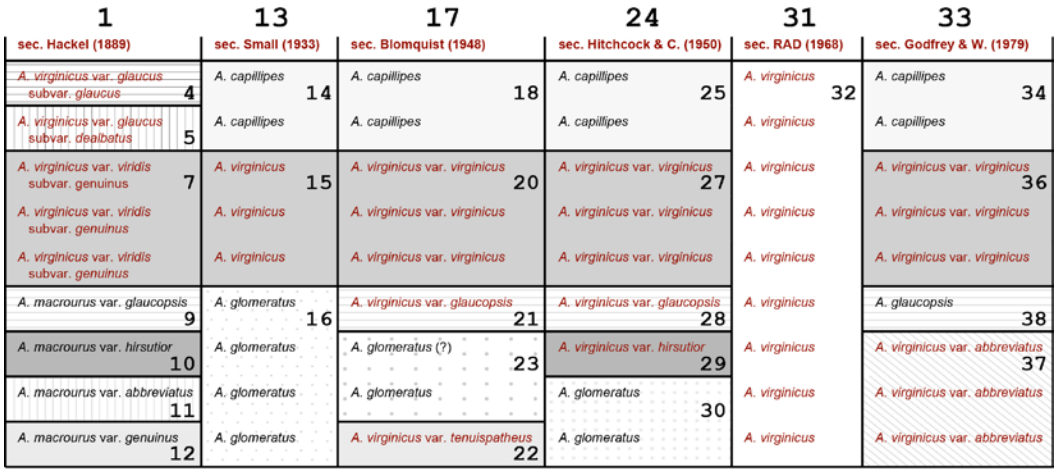
[1] SERNEC portal, May 15, 2015; with synonyms, raw taxonomy.

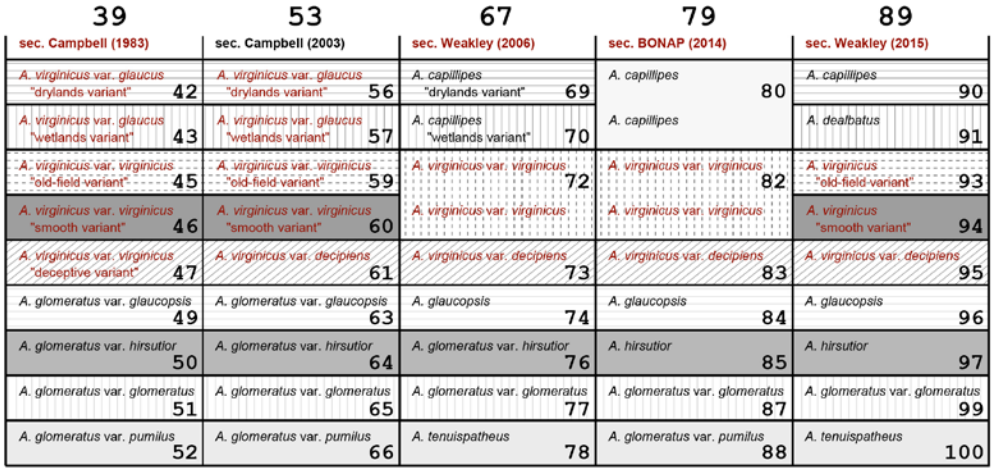
Ready to do science?

Maybe. There are some issues.

Taxonomic concept alignment, *Andropogon glomeratus-virginicus* complex, spanning across 11 classifications authored 1889-2015

- **36** unique taxonomic names
- **88** taxonomic concept labels
  - name sec. author strings
- **Alignment** by A.S. Weakley
  - row position = congruence
- **1/36 names** with unique 1 : 1 name : meaning cardinality across all classifications
- ***Andropogon virginicus***
- **Source:** Franz *et al.* 2015[1]



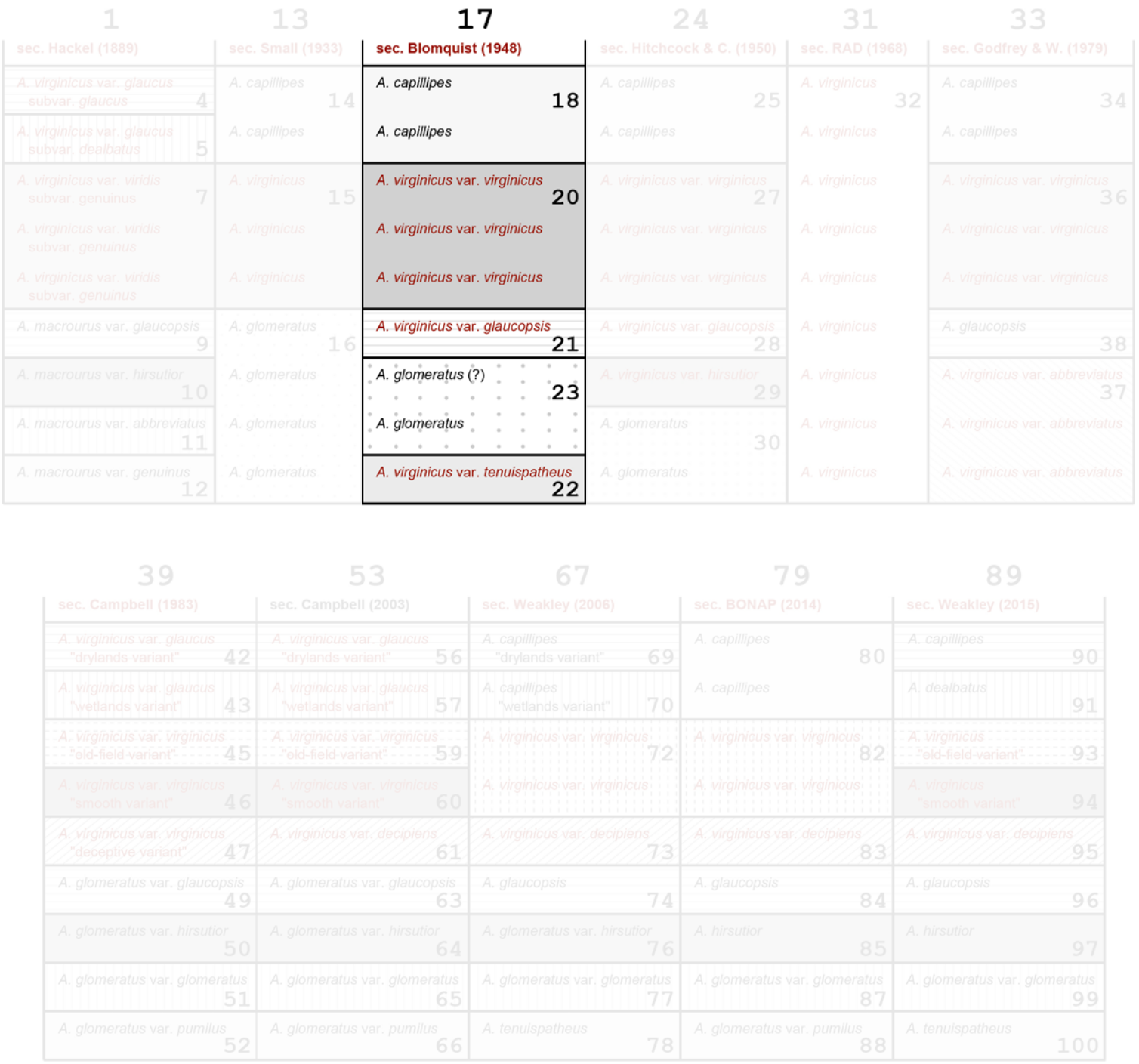


[1] Franz *et al.* 2015. Names are not good enough: reasoning over taxonomic change in the *Andropogon* complex. Semantic Web Journal. http://www.semantic-web-journal.net/system/files/swj1027.pdf

This is how we built this.

1	13	17	24	31	33
sec. Hackel (1889)	sec. Small (1933)	sec. Blomquist (1948)	sec. Hitchcock & C. (1950)	sec. RAD (1968)	sec. Godfrey & W. (1979)
A. virginicus var. *glaucus* subvar. *glaucus* 4	*A. capillipes* 14	*A. capillipes* 18	*A. capillipes* 25	*A. virginicus* 32	*A. capillipes* 34
A. virginicus var. *glaucus* subvar. *dealbatus* 5	*A. capillipes*	*A. capillipes*	*A. capillipes*	*A. virginicus*	*A. capillipes*
A. virginicus var. *viridis* subvar. *genuinus* 7	*A. virginicus* 15	*A. virginicus* var. *virginicus* 20	*A. virginicus* var. *virginicus* 27	*A. virginicus*	*A. virginicus* var. *virginicus* 36
A. virginicus var. *viridis* subvar. *genuinus*	*A. virginicus*	*A. virginicus* var. *virginicus*	*A. virginicus* var. *virginicus*	*A. virginicus*	*A. virginicus* var. *virginicus*
A. virginicus var. *viridis* subvar. *genuinus*	*A. virginicus*	*A. virginicus* var. *virginicus*	*A. virginicus* var. *virginicus*	*A. virginicus*	*A. virginicus* var. *virginicus*
A. macrourus var. *glaucopsis* 9	*A. glomeratus* 16	*A. virginicus* var. *glaucopsis* 21	*A. virginicus* var. *glaucopsis* 28	*A. virginicus*	*A. glaucopsis* 38
A. macrourus var. *hirsutior* 10	*A. glomeratus*	*A. glomeratus* (?) 23	*A. virginicus* var. *hirsutior* 29	*A. virginicus*	*A. virginicus* var. *abbreviatus* 37
A. macrourus var. *abbreviatus* 11	*A. glomeratus*	*A. glomeratus*	*A. glomeratus* 30	*A. virginicus*	*A. virginicus* var. *abbreviatus*
A. macrourus var. *genuinus* 12	*A. glomeratus*	*A. virginicus* var. *tenuispatheus* 22	*A. glomeratus*	*A. virginicus*	*A. virginicus* var. *abbreviatus*

39	53	67	79	89
sec. Campbell (1983)	sec. Campbell (2003)	sec. Weakley (2006)	sec. BONAP (2014)	sec. Weakley (2015)
A. virginicus var. *glaucus* "drylands variant" 42	*A. virginicus* var. *glaucus* "drylands variant" 56	*A. capillipes* "drylands variant" 69	*A. capillipes* 80	*A. capillipes* 90
A. virginicus var. *glaucus* "wetlands variant" 43	*A. virginicus* var. *glaucus* "wetlands variant" 57	*A. capillipes* "wetlands variant" 70	*A. capillipes*	*A. dealbatus* 91
A. virginicus var. *virginicus* "old-field variant" 45	*A. virginicus* var. *virginicus* "old-field variant" 59	*A. virginicus* var. *virginicus* 72	*A. virginicus* var. *virginicus* 82	*A. virginicus* "old-field variant" 93
A. virginicus var. *virginicus* "smooth variant" 46	*A. virginicus* var. *virginicus* "smooth variant" 60	*A. virginicus* var. *virginicus*	*A. virginicus* var. *virginicus*	*A. virginicus* "smooth variant" 94
A. virginicus var. *virginicus* "deceptive variant" 47	*A. virginicus* var. *deciplens* 61	*A. virginicus* var. *deciplens* 73	*A. virginicus* var. *deciplens* 83	*A. virginicus* var. *deciplens* 95
A. glomeratus var. *glaucopsis* 49	*A. glomeratus* var. *glaucopsis* 63	*A. glaucopsis* 74	*A. glaucopsis* 84	*A. glaucopsis* 96
A. glomeratus var. *hirsutior* 50	*A. glomeratus* var. *hirsutior* 64	*A. glomeratus* var. *hirsutior* 76	*A. hirsutior* 85	*A. hirsutior* 97
A. glomeratus var. *glomeratus* 51	*A. glomeratus* var. *glomeratus* 65	*A. glomeratus* var. *glomeratus* 77	*A. glomeratus* var. *glomeratus* 87	*A. glomeratus* var. *glomeratus* 99
A. glomeratus var. *pumilus* 52	*A. glomeratus* var. *pumilus* 66	*A. tenuispatheus* 78	*A. glomeratus* var. *pumilus* 88	*A. tenuispatheus* 100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A. capillipes 14
A. capillipes
A. virginicus 15
A. virginicus
A. virginicus
A. glomeratus 16
A. glomeratus
A. glomeratus
A. glomeratus
17
sec. Blomquist (1948)
A. capillipes 18
A. capillipes
A. virginicus var. virginicus 20
A. virginicus var. virginicus
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A. virginicus var. glaucopsis 21
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A. glomeratus
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A. capillipes 25
A. capillipes
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A. virginicus var. glaucopsis 28
A. virginicus var. hirsutior 29
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sec. RAD (1968)
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A. glomeratus var. glomeratus 51
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A. glomeratus var. glomeratus 65
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sec. Weakley (2006)
A. capillipes "drylands variant" 69
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A. virginicus var. virginicus 72
A. virginicus var. virginicus
A. virginicus var. decipiens 73
A. glaucopsis 74
A. glomeratus var. hirsutior 76
A. glomeratus var. glomeratus 77
A. tenuispatheus 78
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sec. BONAP (2014)
A. capillipes 80
A. capillipes
A. virginicus var. virginicus 82
A. virginicus var. virginicus
A. virginicus var. decipiens 83
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A. dealbatus 91
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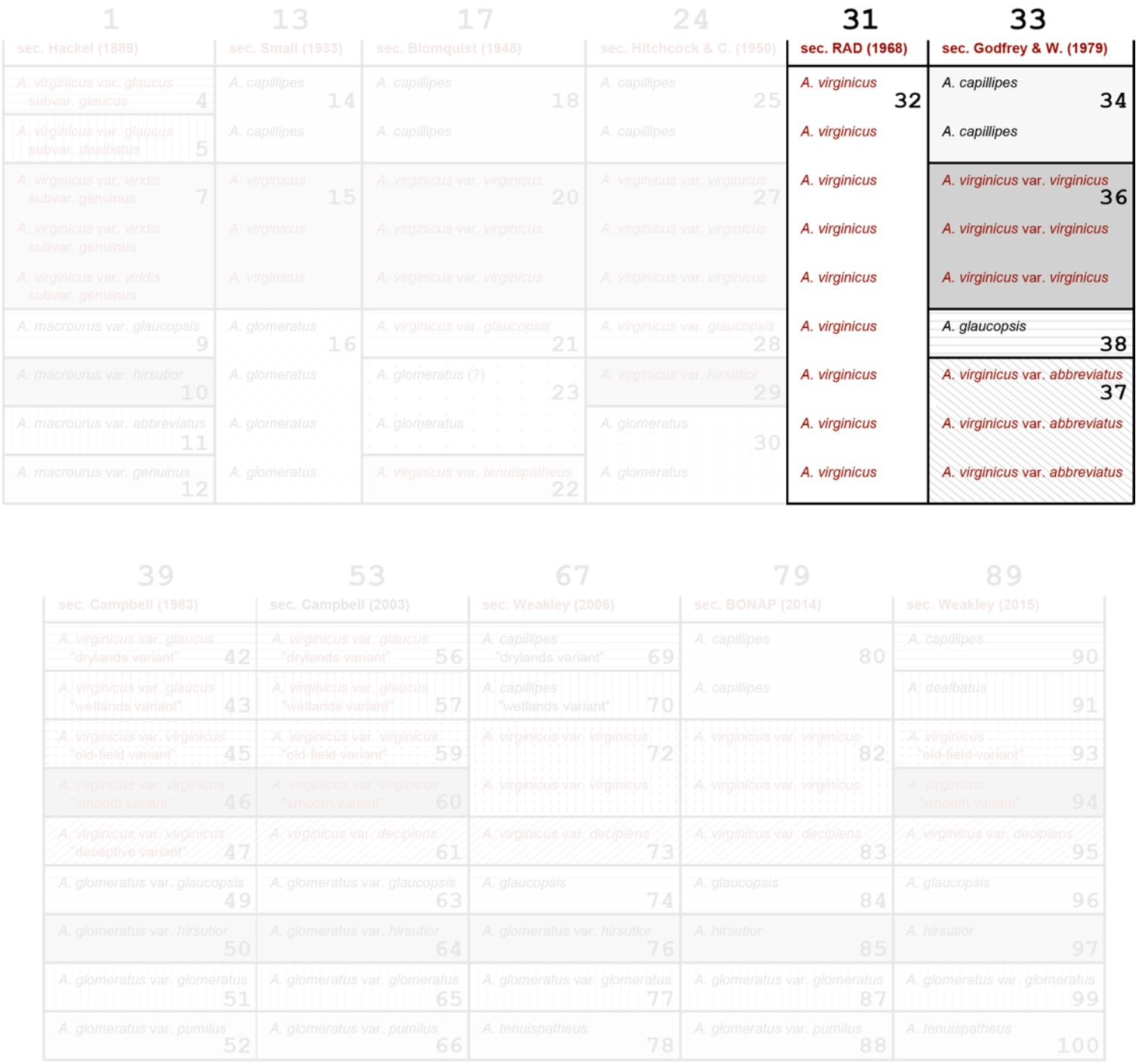
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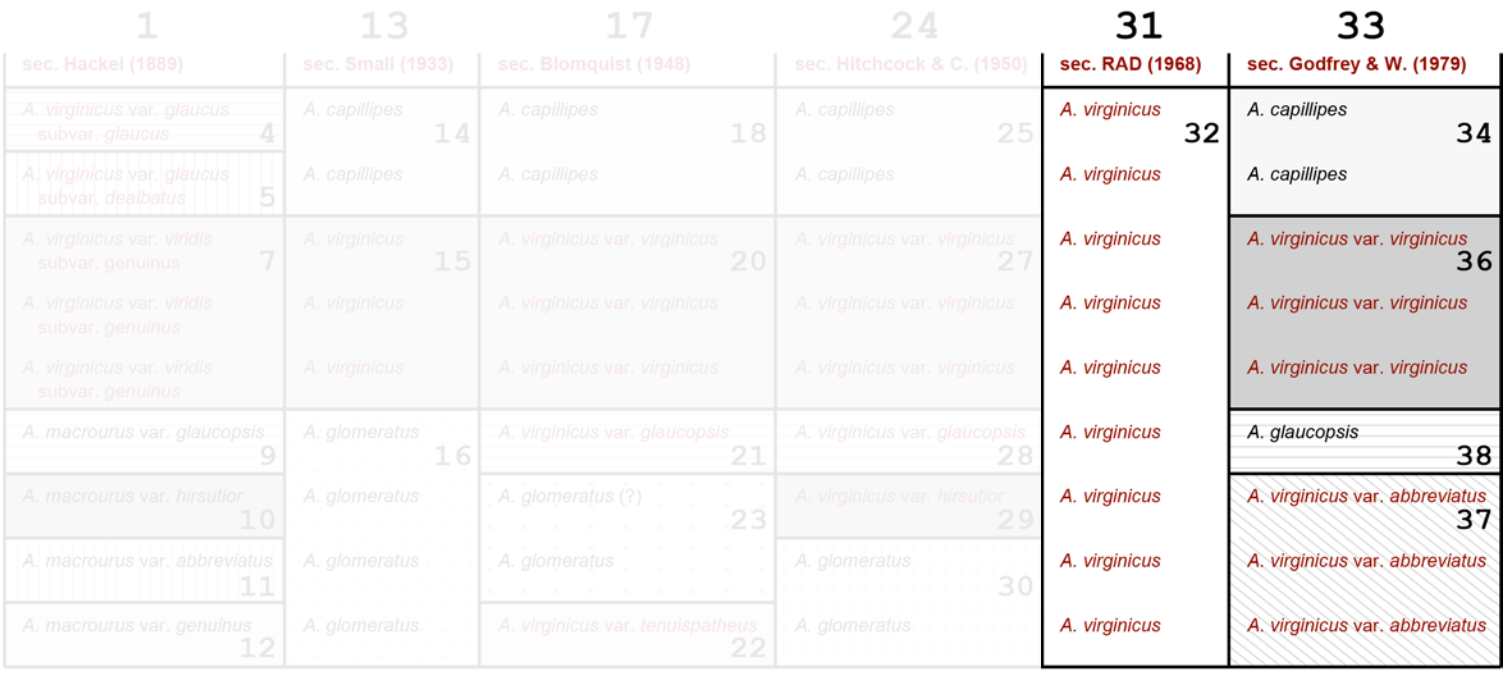
1
sec. Hackel (1889)
A. virginicus var. glaucus subvar. glaucus 4
A. virginicus var. glaucus subvar. dealbatus 5
A. virginicus var. viridis subvar. genuinus 7
A. virginicus var. viridis subvar. genuinus
A. virginicus var. viridis subvar. genuinus
A. macrourus var. glaucopsis 9
A. macrourus var. hirsutior 10
A. macrourus var. abbreviatus 11
A. macrourus var. genuinus 12
13
sec. Small (1933)
A. capillipes 14
A. capillipes
A. virginicus 15
A. virginicus
A. virginicus
A. glomeratus 16
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A. glomeratus
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sec. Blomquist (1948)
A. capillipes 18
A. capillipes
A. virginicus var. virginicus 20
A. virginicus var. virginicus
A. virginicus var. virginicus
A. virginicus var. glaucopsis 21
A. glomeratus (?) 23
A. glomeratus
A. virginicus var. tenuispatheus 22
24
sec. Hitchcock & C. (1950)
A. capillipes 25
A. capillipes
A. virginicus var. virginicus 27
A. virginicus var. virginicus
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A. virginicus var. glaucopsis 28
A. virginicus var. hirsutior 29
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31
sec. RAD (1968)
A. virginicus 32
A. virginicus
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A. virginicus
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33
sec. Godfrey & W. (1979)
A. capillipes 34
A. capillipes
A. virginicus var. virginicus 36
A. virginicus var. virginicus
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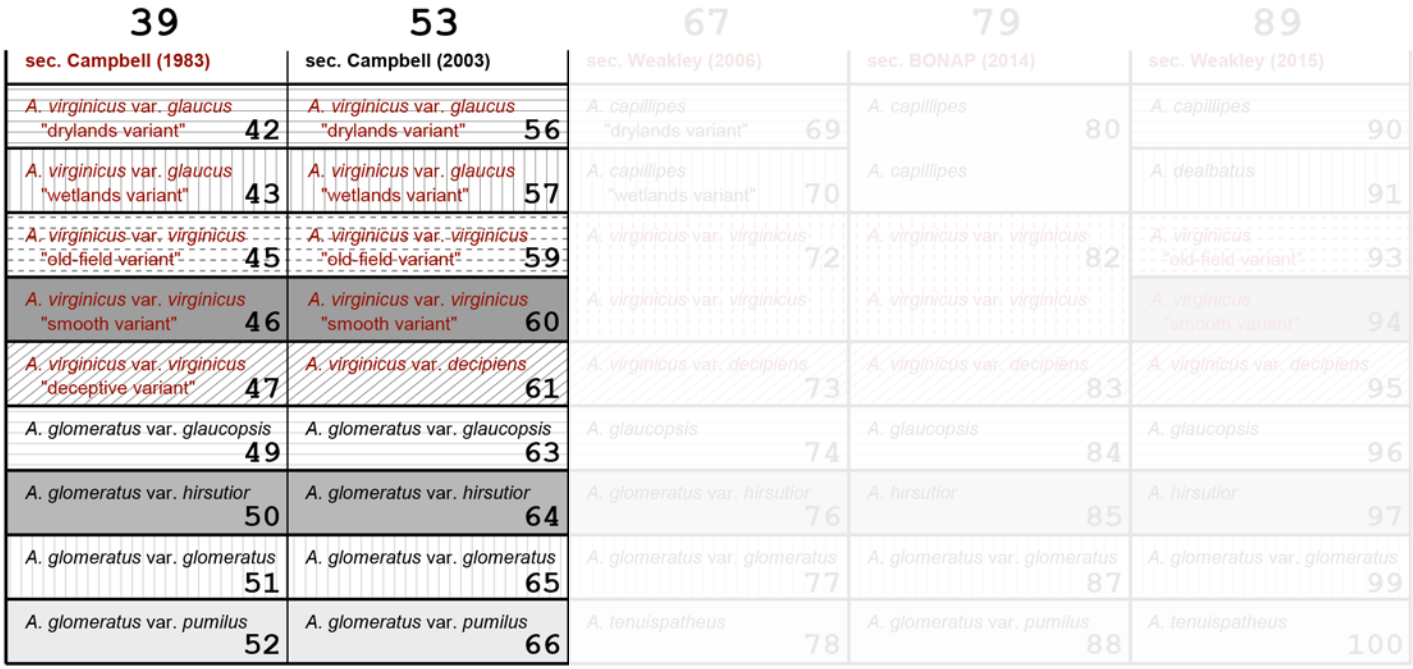
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A. glomeratus var. pumilus 52
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A. glomeratus var. pumilus 66
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sec. Weakley (2006)
A. capillipes "drylands variant" 69
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A. virginicus var. virginicus
A. virginicus var. decipiens 73
A. glaucopsis 74
A. glomeratus var. hirsutior 76
A. glomeratus var. glomeratus 77
A. tenuispatheus 78
79
sec. BONAP (2014)
A. capillipes 80
A. capillipes
A. virginicus var. virginicus 82
A. virginicus var. virginicus
A. virginicus var. decipiens 83
A. glaucopsis 84
A. hirsutior 85
A. glomeratus var. glomeratus 87
A. glomeratus var. pumilus 88
89
sec. Weakley (2015)
A. capillipes 90
A. dealbatus 91
A. virginicus "old-field variant" 93
A. virginicus "smooth variant" 94
A. virginicus var. decipiens 95
A. glaucopsis 96
A. hirsutior 97
A. glomeratus var. glomeratus 99
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A. glomeratus var. glomeratus 99
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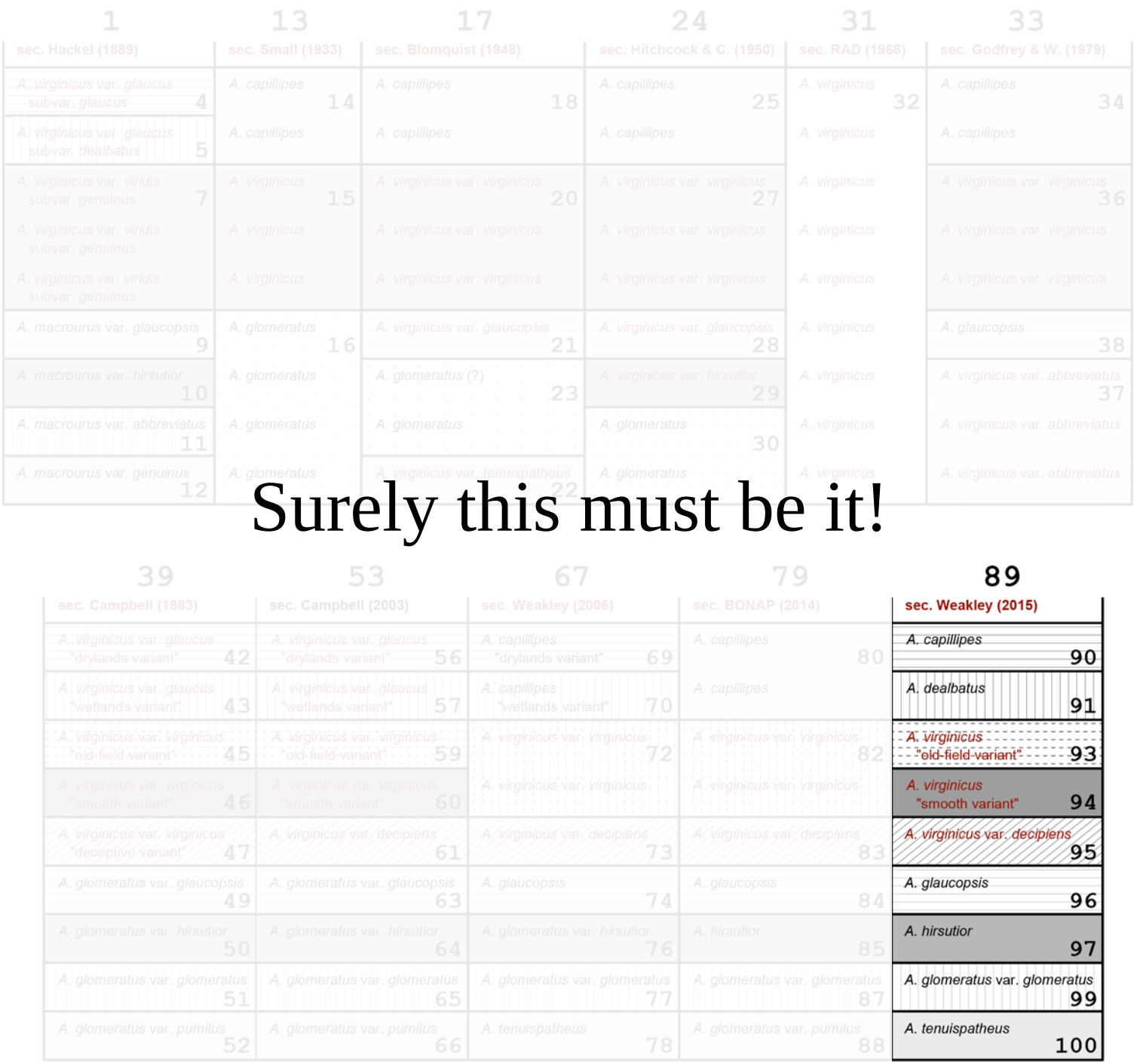
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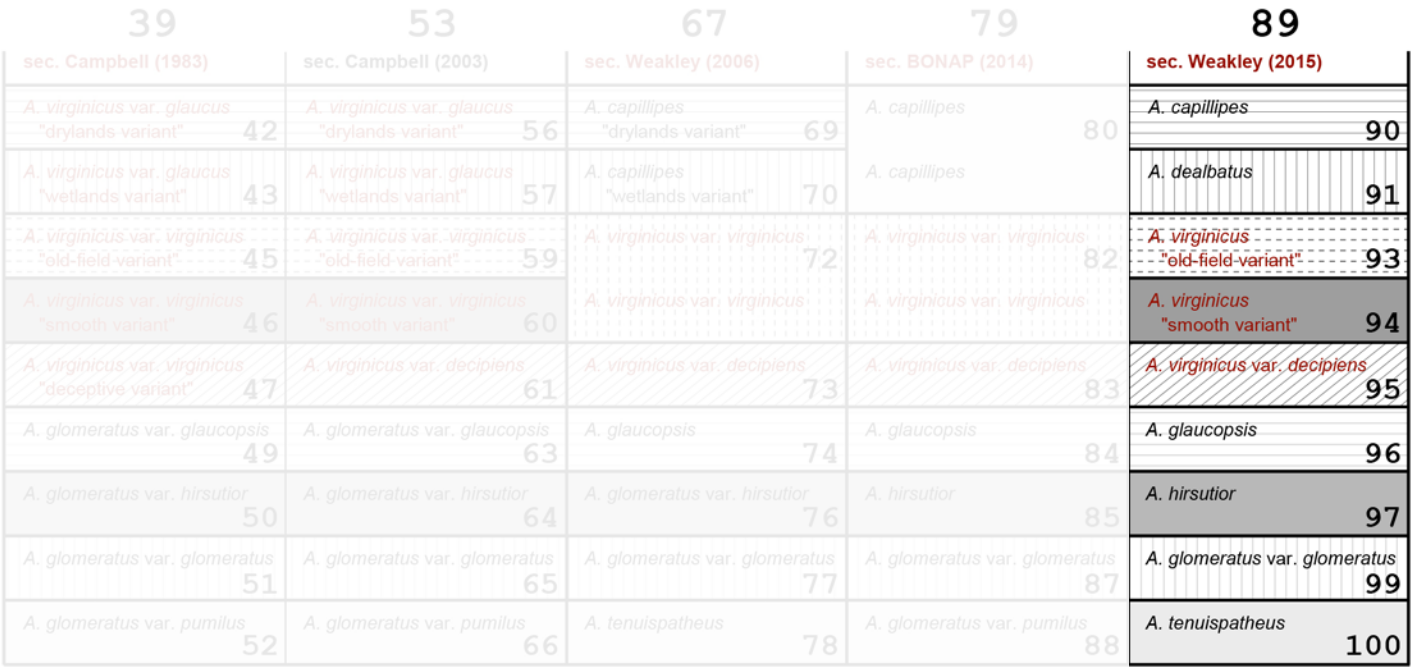
A. tenuispatheus 100

The Catalogue of *Andropogon*

By us

From here on out, and until Infinity

Surely this must be it!



The Catalogue of *Andropogon*

By us

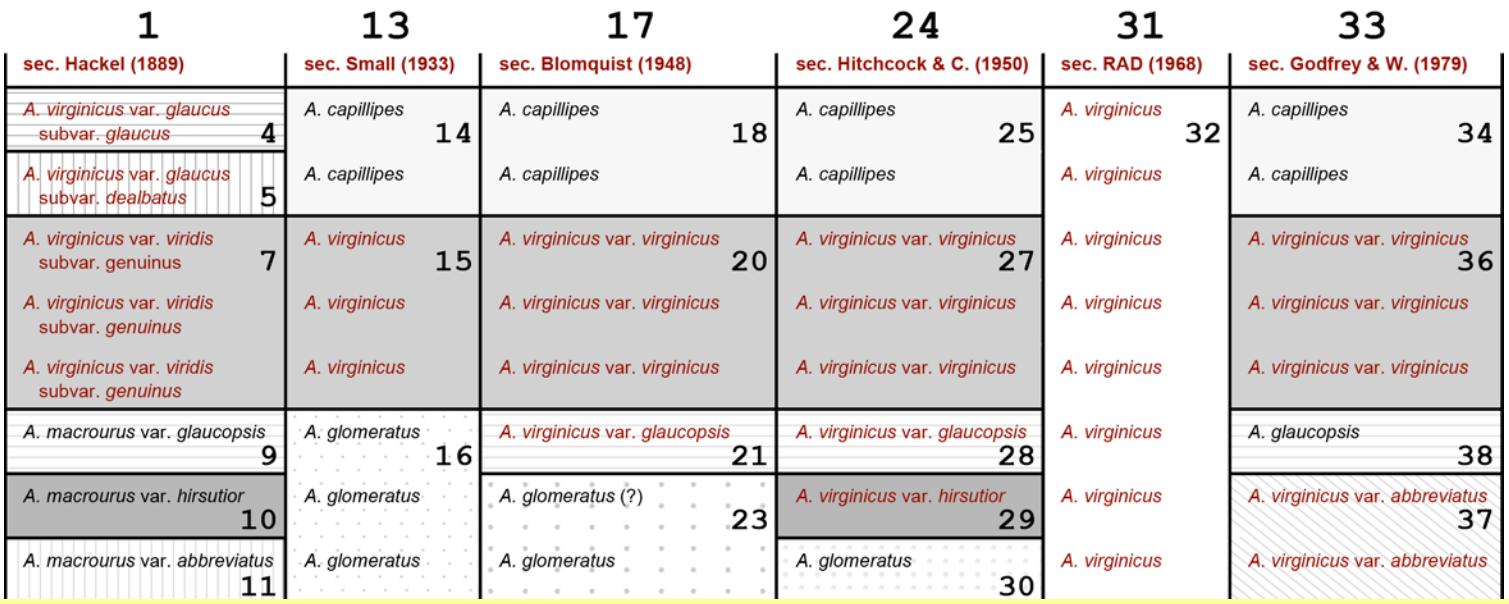
From here on out, and until Infinity

not.

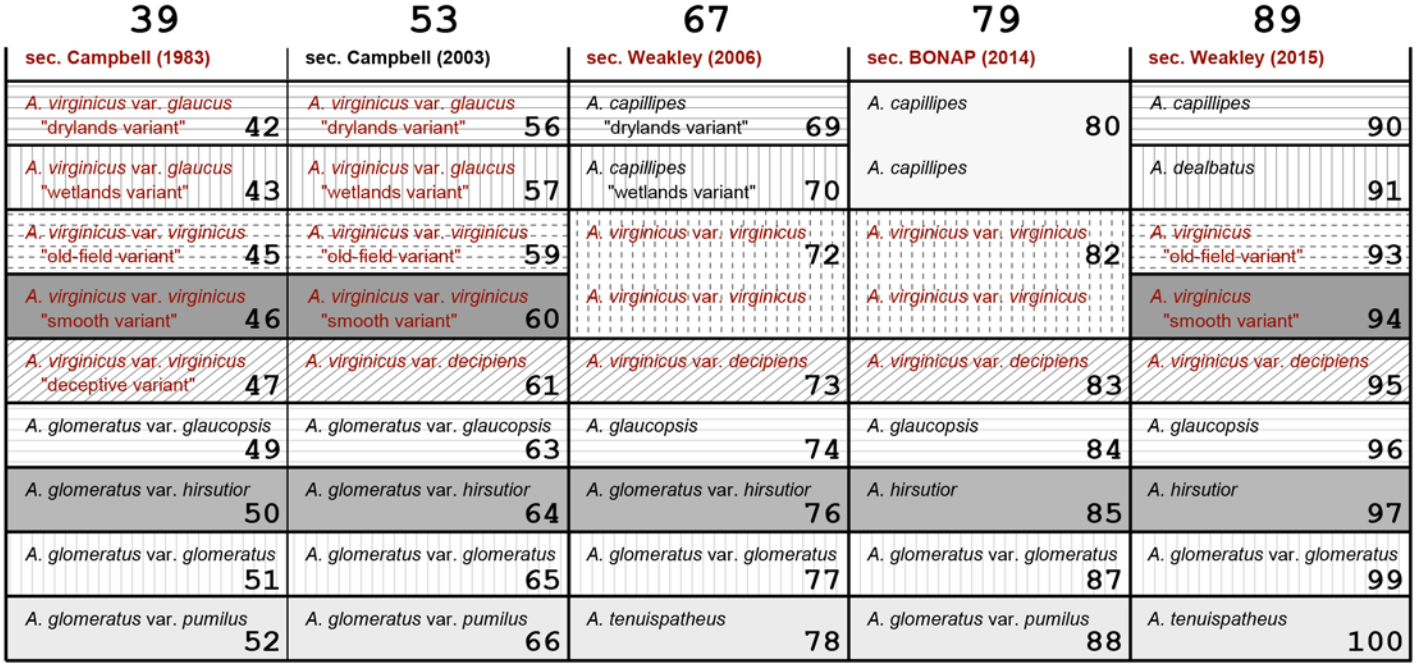
The current stage of the likely continuously evolving sequence of *human* taxonomy making, with limited (nomenclatural) resolution to preceding stages - even though these were used to identify many specimens we retain in our collections - and without adequate semantic infrastructure to identify, accommodate, and logically connect the next century of stages.

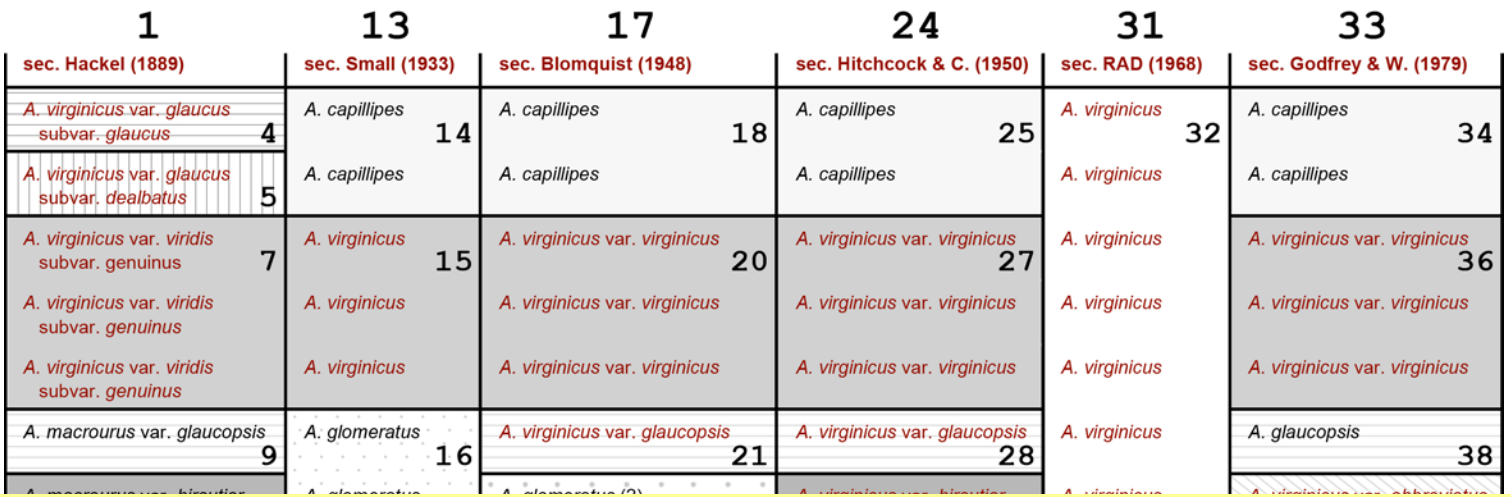
~~Three~~ Four Great Narcissistic Wounds

- **Copernicus:** We are *no*t the center of the universe.
- **Darwin:** We are *not* uniquely, purposefully created.
- **Freud:** The rational does *not* reign over our minds.
- **Our successors:** Our taxonomy was ***not*** **"of Life".**

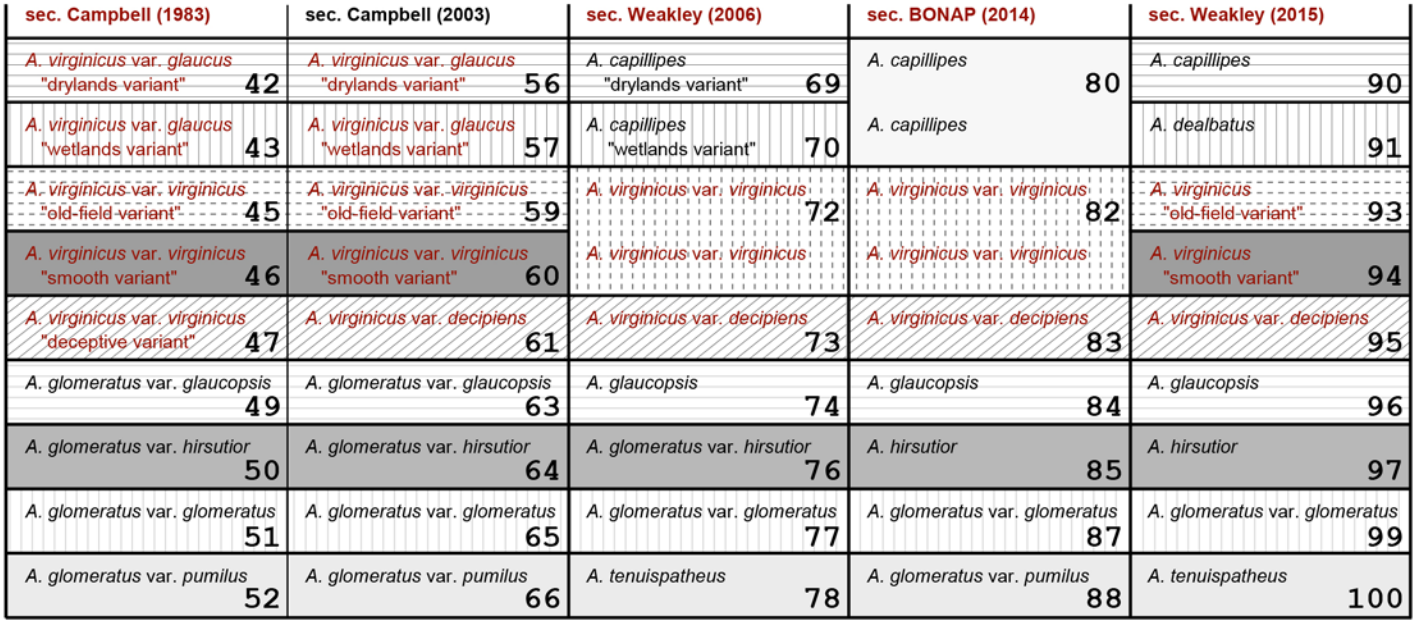


This should become our new favorite logo.





Claim: We can build voucher-based environments that **represent every concept identifier** (taxonomic concept label), and which can store and reason over **semantic articulations** among these.

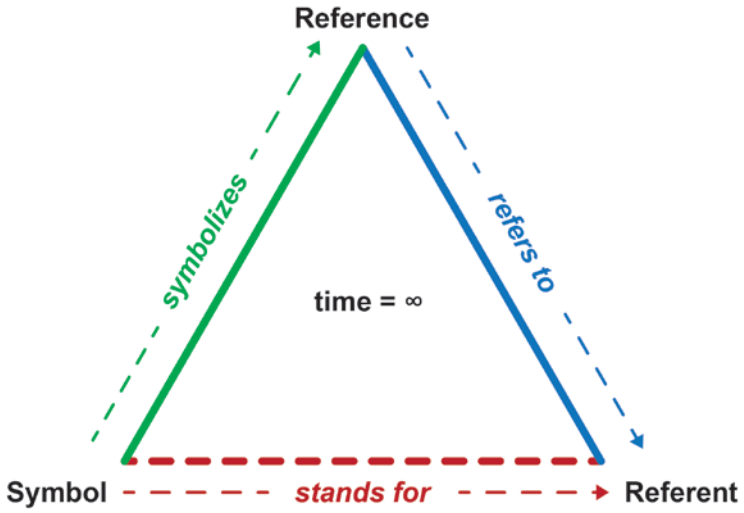


Let's outline a stepwise solution.

Step 1. Diagnose the opportunity for better semantics

The Semiotic Triangle[1]

- **A Symbol** (name) symbolizes a **Reference** (human-made concept, theory), which in turn refers to a **Referent** (phenomenon in the world).
- In human communication, the **Symbol also stands for the Referent;** however, this **relationship is imputed** (i.e., subject to corrections).

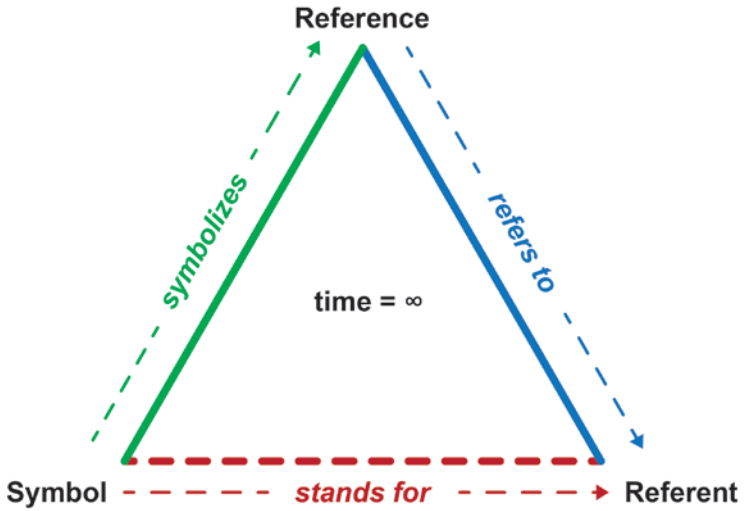


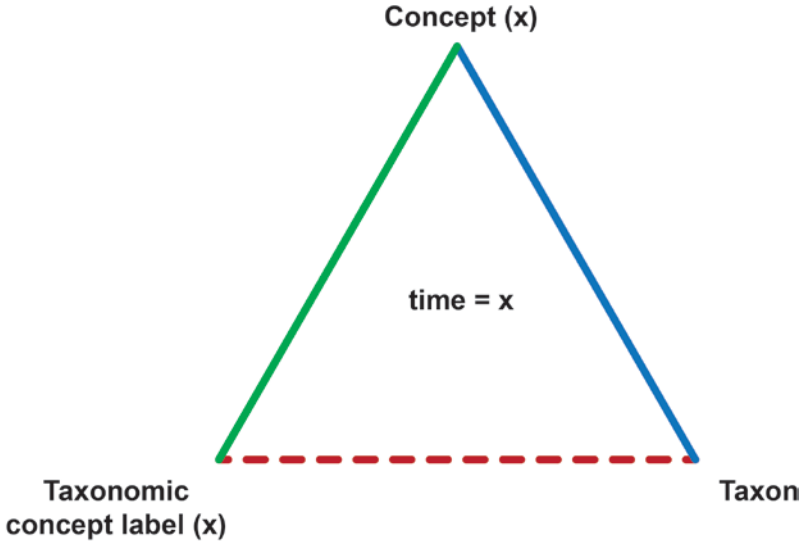
[1] Source: Ogden & Richards. 1923. The Meaning of Meaning. 8th Edition. Brace & World, Inc.

Step 1. Diagnose the opportunity for better semantics

The Semiotic Triangle - for reference to taxonomic concepts

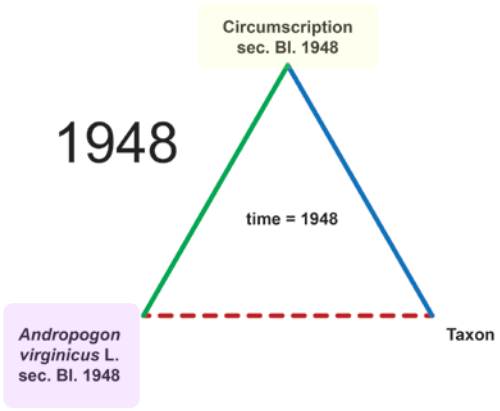
- **A taxonomic concept label** (name sec. author) symbolizes a **taxonomic concept** (human-made theory, authored at a specific time x, about the identity and boundaries of a perceived evolutionary entity).
- The **taxonomic concept** variously succeeds in aligning itself with the **taxon** in nature.

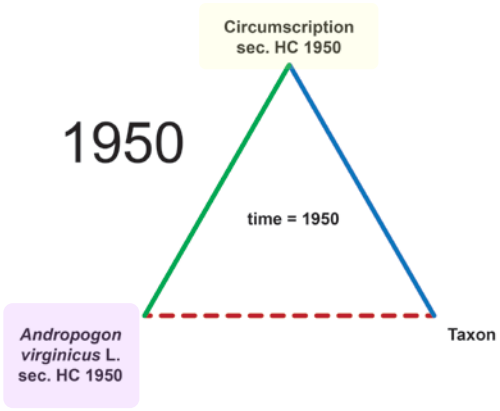


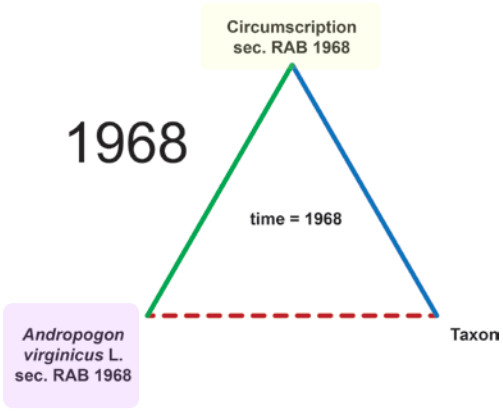


Step 2. Represent taxonomic concept **identity**

- Taxonomic concept labels are **more granular identifiers** in comparison to taxonomic names, but otherwise **retain the same syntactic and semantic advantages.**

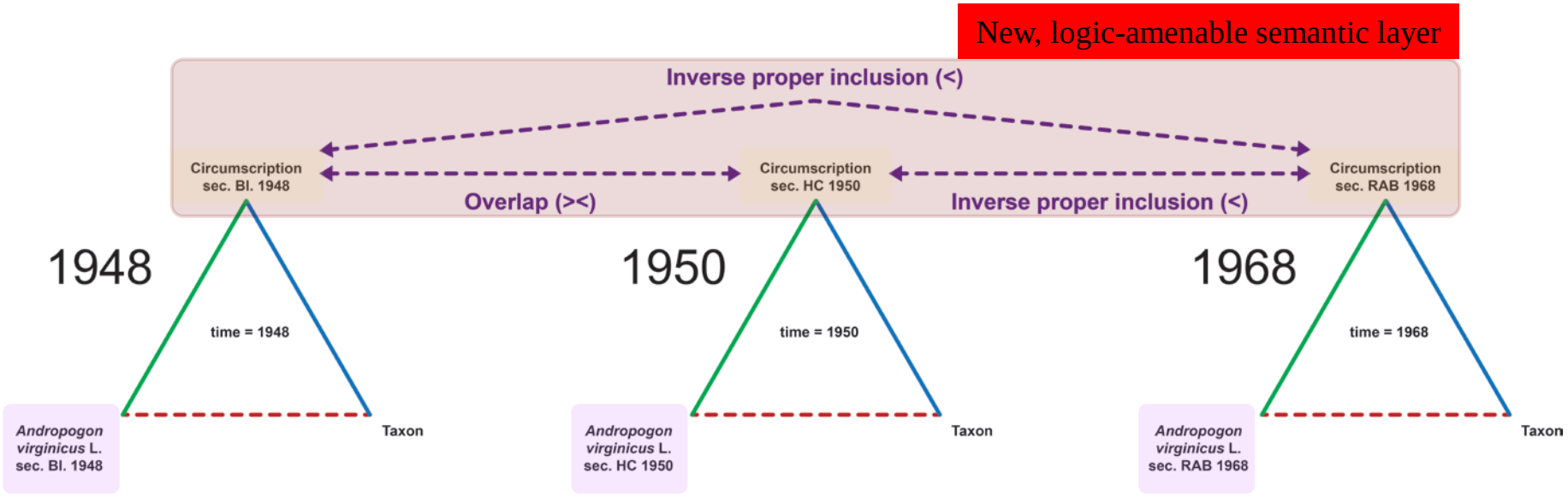






Step 3. Represent taxonomic concept **identifier provenance**

- Granular taxonomic concepts can be semantically reconnected using **articulations.**
- In **Euler/X,** the articulations adopt the **Region Connection Calculus (RCC-5)** terms.
- Multi-concept **resolution services** (non-/congruence) are provided by the articulations.



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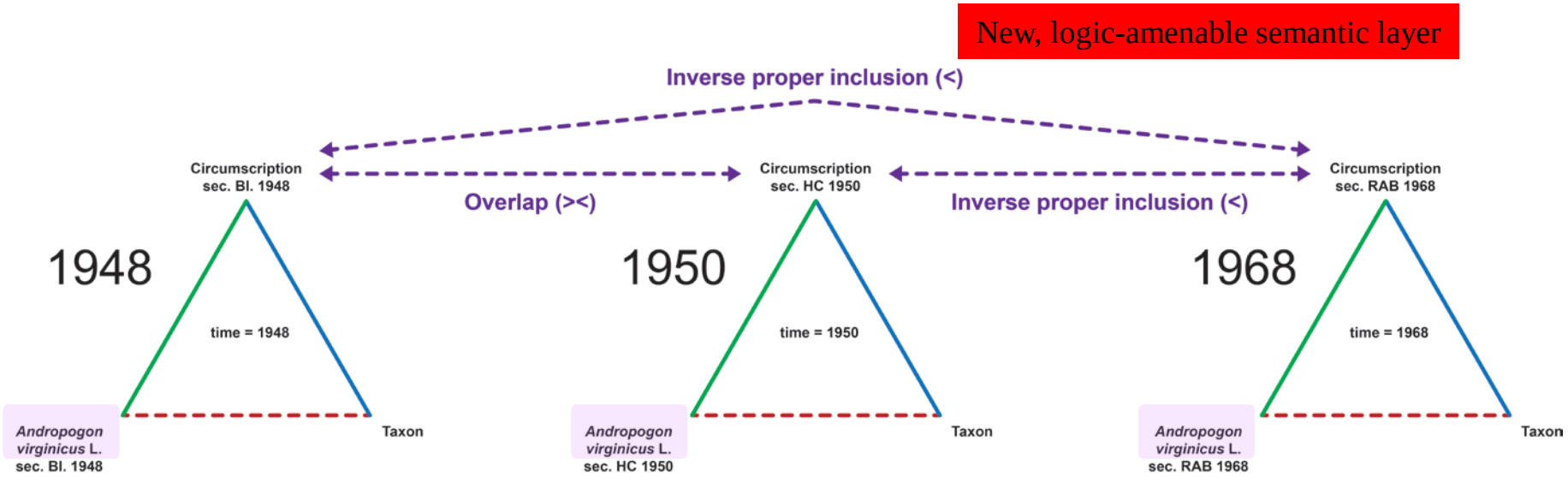

- Under this representation approach, **taxonomic names symbolize** entire, potentially infinite, taxonomic concept **lineages.**
- Using just the name, a logic application cannot identify any specific lineage segment.

Step 4. Euler/X taxonomic concept alignment toolkit[1]

https://github.com/EulerProject/EulerX

EulerX Toolkit Overview

On this page:

Introduction

Euler is an open source toolkit (mostly written in Python) for merging taxonomies (taxonomical organized datasets) and visualizing the results. (see Euler Toolkit Wiki for more information, and the remaining issue list in Jira)

We have all the EulerFO source code, EulerASP source code, and a bunch of use cases in this toolkit. EulerFO is a modified version of CleanTax which was firstly developed by Dave Thau. CleanTax/EulerFO are built upon Prover9/Mace4 reasoning software. EulerASP is a brand new taxonomy reasoning tool that Mingmin built from scratch. EulerASP is built based on popular ASP reasoners DLV and Potassco.

Central goal

Tax_1 + Tax_2 + Art. ☐ Alignment

Command line interface

```
Andropogon-SWJ-II-2015-Final — bash — 109×49
Last login: Mon May 18 13:39:00 on console
NMF:~ NMF$ cd EulerX/
NMF:EulerX NMF$ cd /Users/NMF/euler-project/NMF-Euler/andro-2014/Andropogon-SWJ-II-2015-Final/
NMF:Andropogon-SWJ-II-2015-Final NMF$ euler2 --help
Euler CLI 2.0 doc

Usage:
       euler2 (-h | --help)
       euler2 --version
       euler2 check <inputfile>
       euler2 align <inputfile>... [-e METHOD] [-r TOOL] [--consistency] [--hidemirdisjoint] [--disablecov]
[--disablesib] [--repair=WAY] [--artRem] [--fourinone] [--xia] [--ur] [--ie] [--ieo]
       euler2 show <name>
       euler2 show <run> <name>


Options:
    -h --help           Show this screen.
    --version           Show version.
    -e METHOD           Set the encoding method [default: mnpw].
    -r TOOL             Set the reasoner [default: dlv].
    --consistency       Check consistency ONLY.
    --disablecov        Disable coverage.
    --disablesib        Disable sibling disjointness.
    --repair WAY        Repair inconsistency [default: HST].
    --artRem            Articulation remover.
    <run>               The alignment run you want to show, by default is last run if not specified.
    <name>              The knowledge product you want to show, including:
                              iv (input visualization)
                              pw (possible worlds)
                              av (aggregate view)
                              cv (cluster view)
                              hv (hierarchy view)
                              inconLat (inconsistency lattice, BETA)
                              ambLat (ambiguity lattice, BETA)
                              pw2input (taxonomy that converted from PW, BETA)
NMF:Andropogon-SWJ-II-2015-Final NMF$ euler2 align figure4C.txt
******* You are running example figure4C *******

Possible world 0:
{1950.A_virginicus_var_glaucopsis"!"1948.A_glomeratus, 1950.A_capillipes"!"1948.A_glomeratus, 1950.A_virginic
us_var_virginicus"!"1948.A_glomeratus, 1950.A_virginicus_var_virginicus"!"1948.A_capillipes, 1950.A_virginicu
s"!"1948.A_capillipes, 1950.A_glomeratus"!"1948.A_virginicus_var_virginicus, 1950.A_virginicus_var_hirsutior"
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sutior"!"1948.A_virginicus_var_glaucopsis, 1950.A_glomeratus"!"1948.A_virginicus_var_glaucopsis, 1950.A_virgi
```
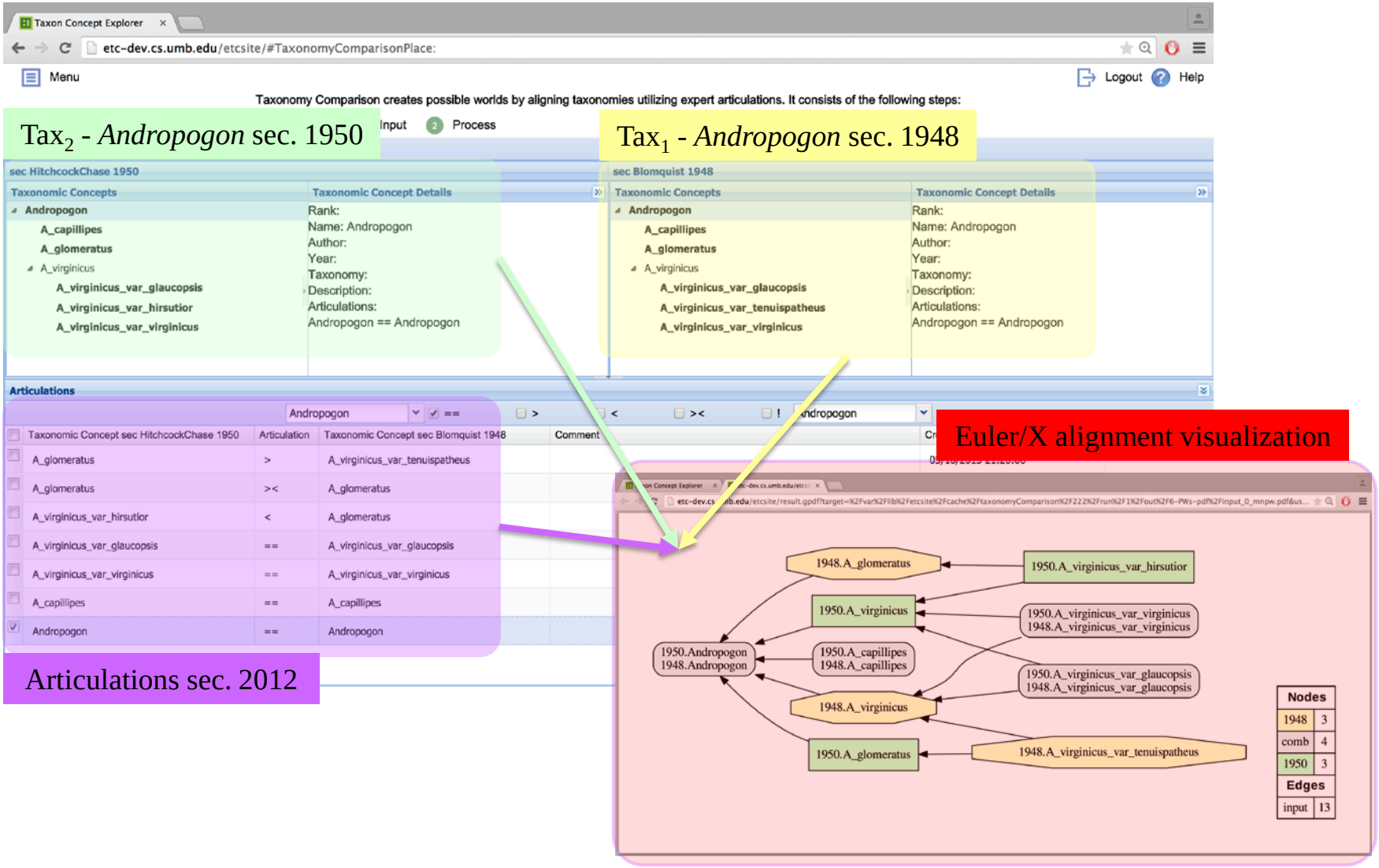

[1] Software available @ https://github.com/EulerProject/EulerX

Integration with Exploring Taxonomic Concepts (ETC)[1]

Combined ETC-Euler/X taxonomy alignment web interface



[1] Project website @ http://taxonconceptexplorer.org/pub/Main_Page

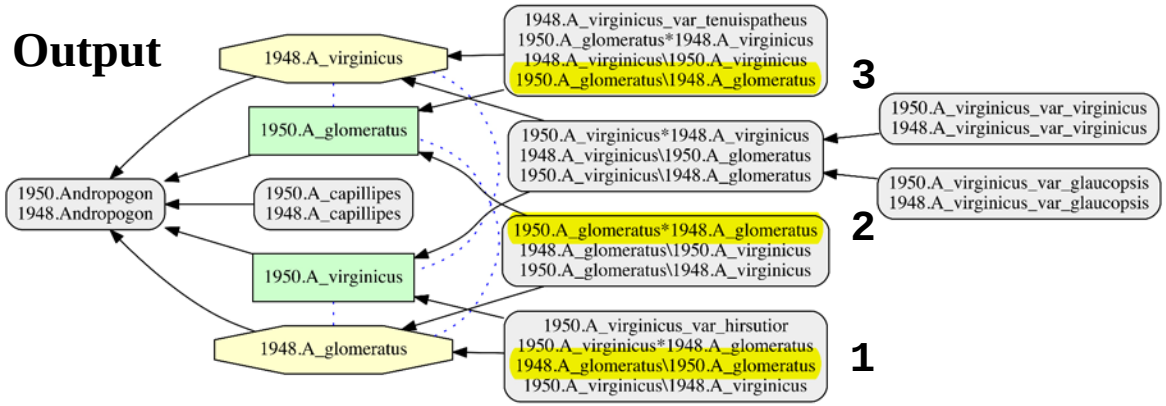
Step 5. Inference and visualization of consistent alignments

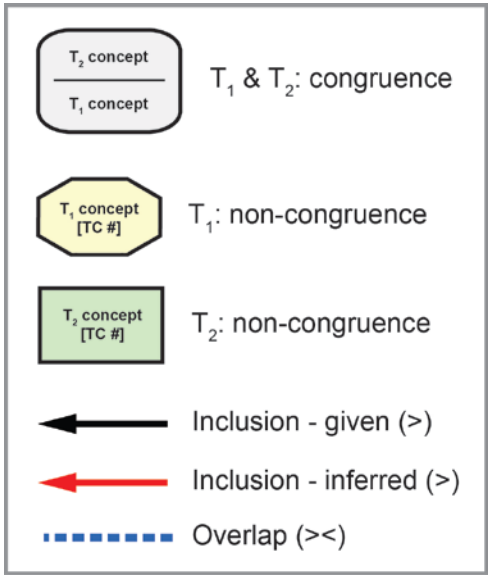
Input

	sec. Blomquist (1948)	sec. Hitchcock & C. (1950)	sec. RAB (1968)
	A. capillipes	*A. capillipes*	*A. virginicus*
	A. capillipes	*A. capillipes*	*A. virginicus*
	A. virginicus var. *virginicus*	***A. virginicus*** var. *virginicus*	*A. virginicus*
	A. virginicus var. *virginicus*	***A. virginicus*** var. *virginicus*	*A. virginicus*
	A. virginicus var. *virginicus*	***A. virginicus*** var. *virginicus*	*A. virginicus*
	A. virginicus var. *glaucopsis*	***A. virginicus*** var. *glaucopsis*	*A. virginicus*
1	*A. glomeratus*	*A. virginicus* var. *hirsutior*	*A. virginicus*
2	*A. glomeratus*	*A. glomeratus*	*A. virginicus*
3	*A. virginicus* var. *tenuispatheus*	*A. glomeratus*	*A. virginicus*

- The toolkit **resolves input constraints into consistent merge regions.**
- In complex, overlapping alignments, some Euler regions are generated for which there are no equivalent labels in either input taxonomy.
  ☐**"merge concepts".**
- Labeling: **A*B** [2], **A**\b [3], **B**\a [1].

Output

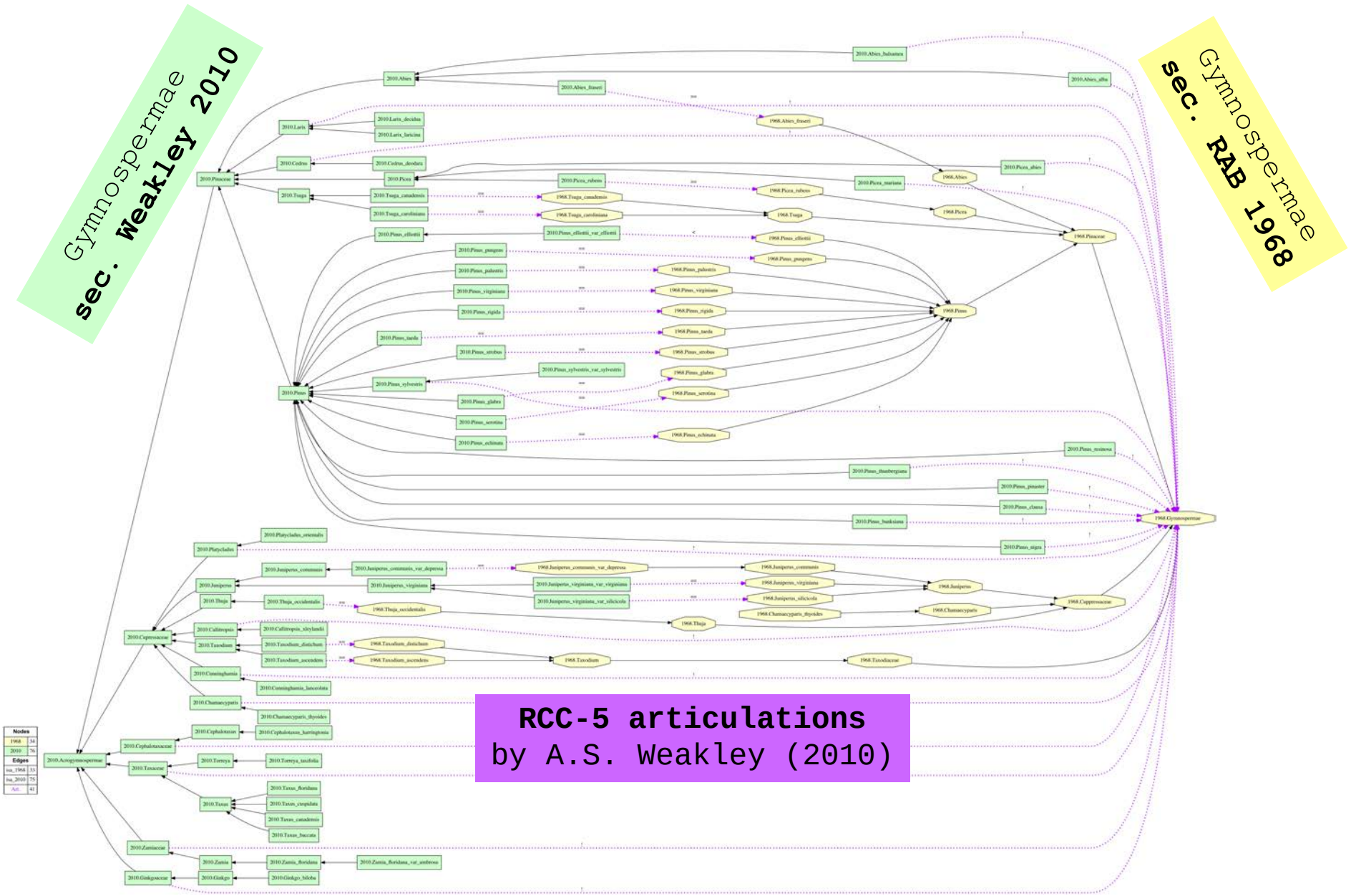




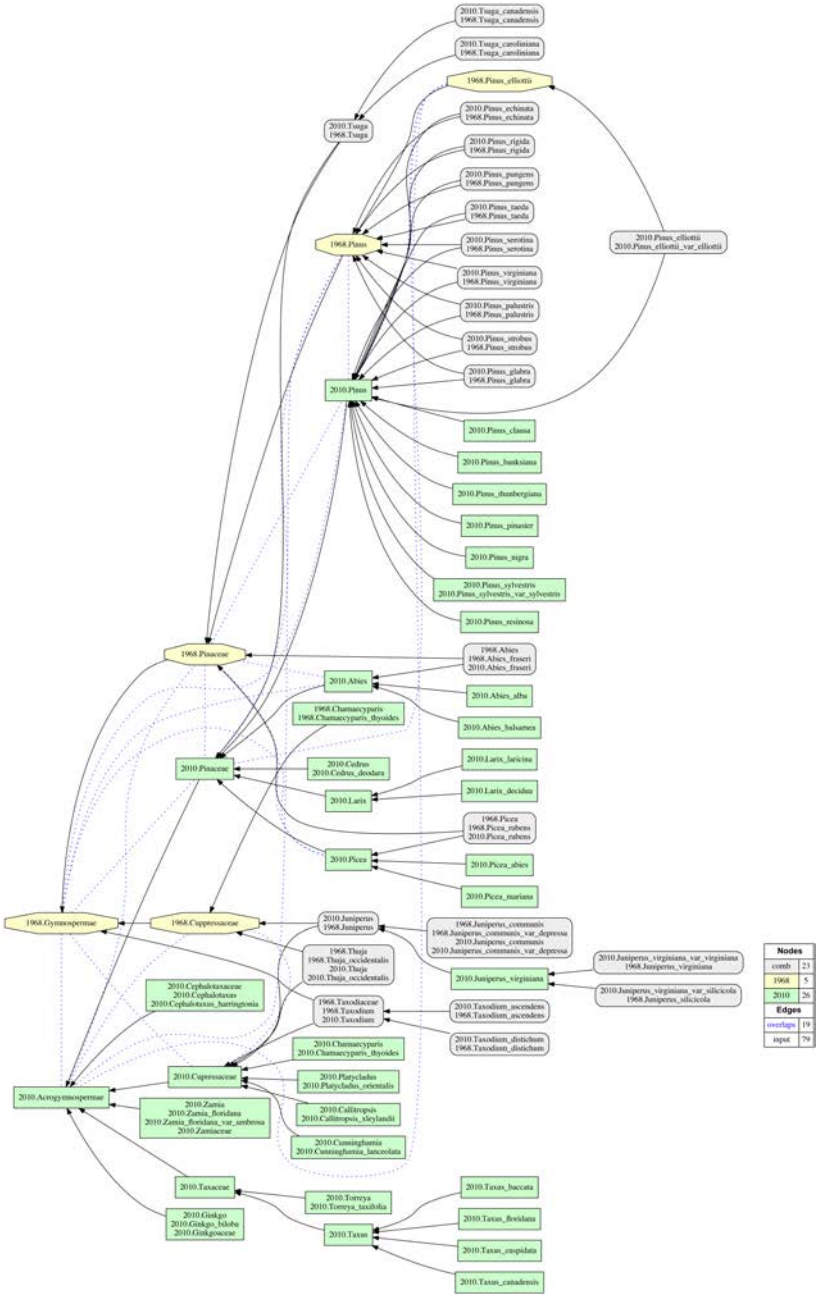
The alignments can scale to the task.[1]

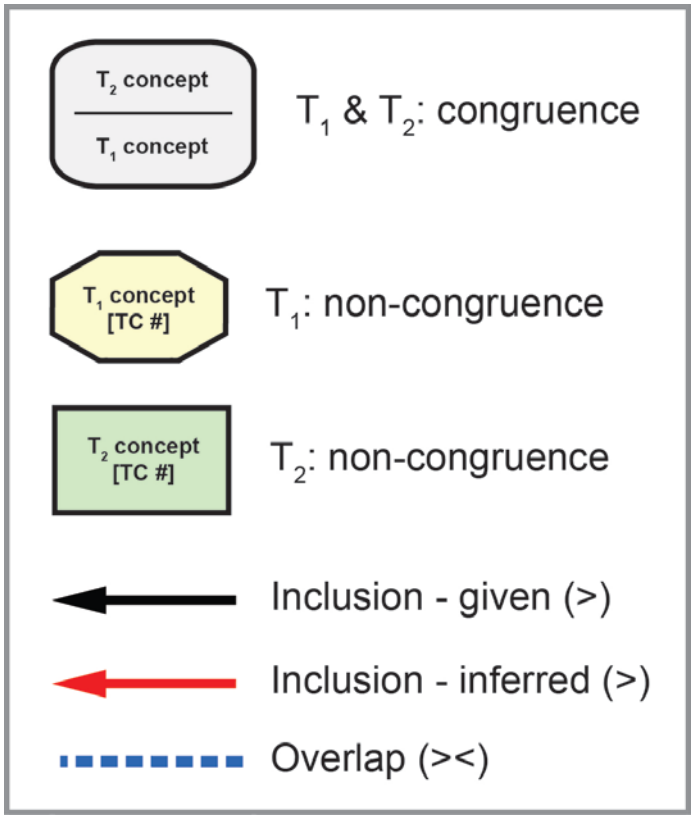
[1] Weakley's 2015 Flora specifies more than 100,000 articulations for Euler/X to utilize towards inter-Flora alignments.

Input visualization - Gymnospermae sec. **2010** versus **1968**



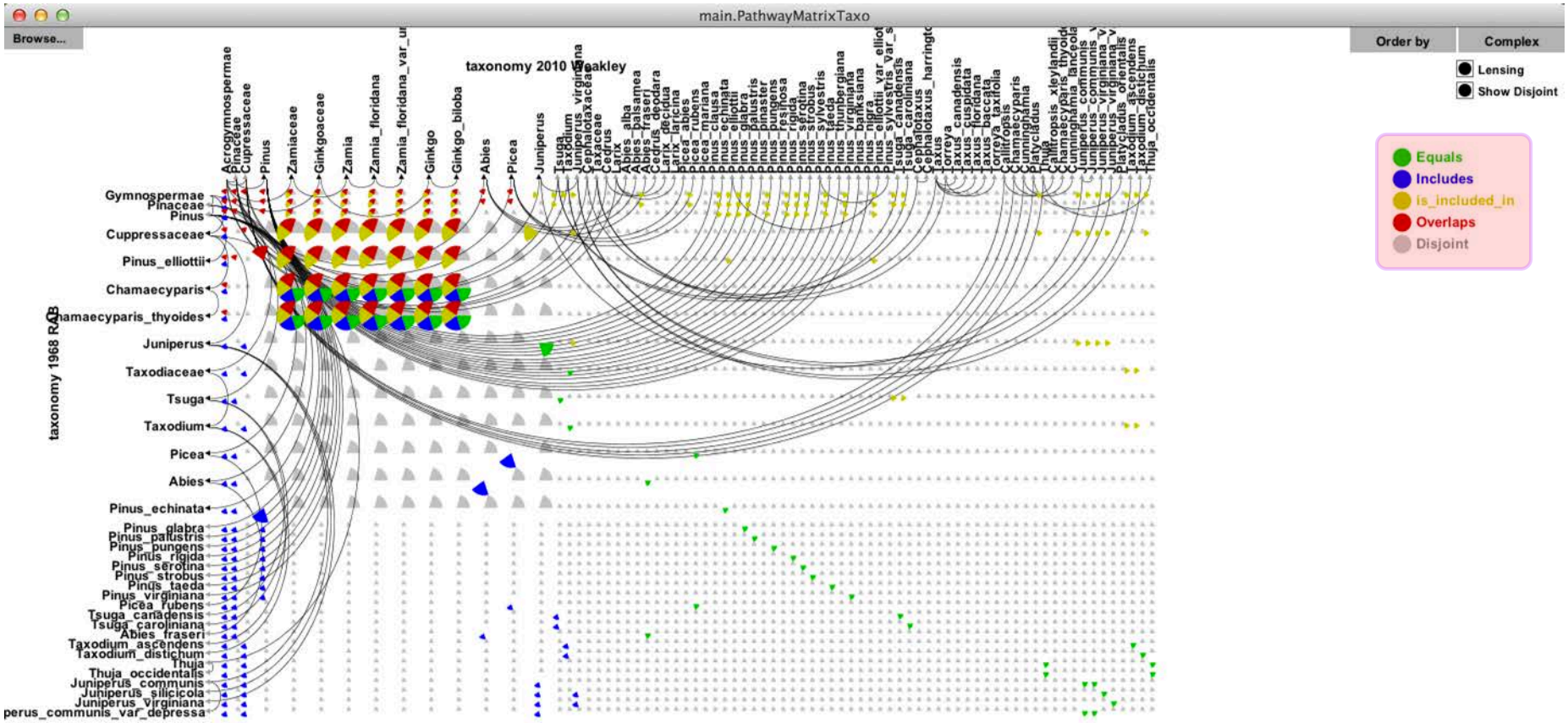
Alignment visualization - Gymnospermae sec. **2010** versus **1968**





MIR visualization (**M**aximally **I**nformative **R**elations)

- MIR = articulations **logically *implied*** by user input, yet not explicitly stated therein
- 76 x 34 input concepts; **41 input articulations**
- **2584 MIR** (reasoning); **only 1.5% of matrix was expressed by the user (Weakley).**
- Explore MIR with **ProvenanceMatrix**[1]



[1] Software available @ https://github.com/CreativeCodingLab/PathwayMatrix

Taxonomic concept resolution - check.

Now back to our voucher-based environment.

(Steps 6-8 are *desired*.)

Step 6. Add taxonomic concept resolution to portal environment[1]

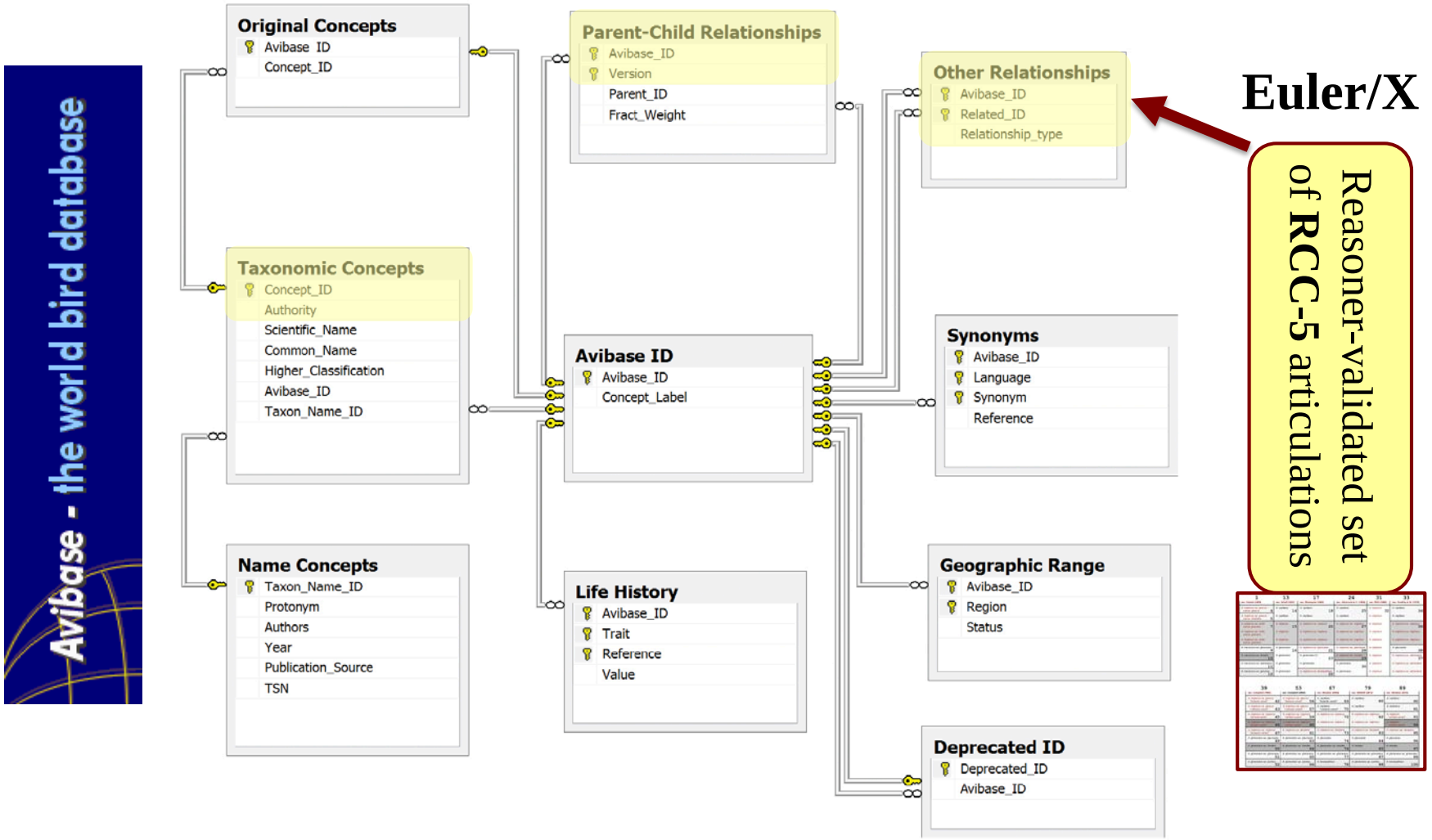
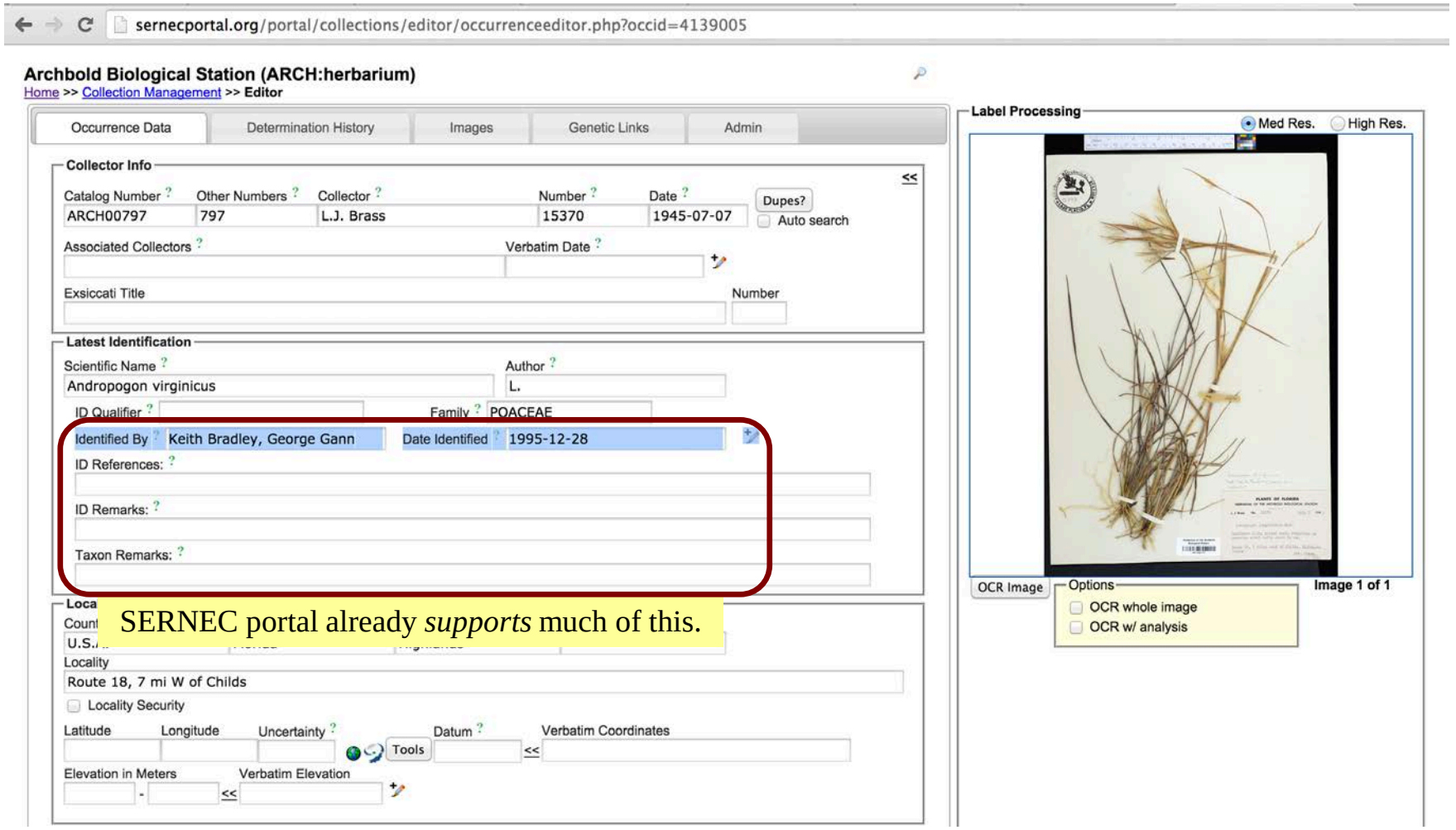


Figure 1. Simplified schema of Avibase primary tables, The Avibase ID table is the central element of Avibase, to which all other concepts are related, and which aims to represent all distinct taxonomic concepts ever published for birds. Published **taxonomic concepts** (species and subspecies, as well as subspe-

[1] Source: Lepage *et al.* 2014. Avibase. ZooKeys 420: 117-135. http://zookeys.pensoft.net/articles.php?id=3906

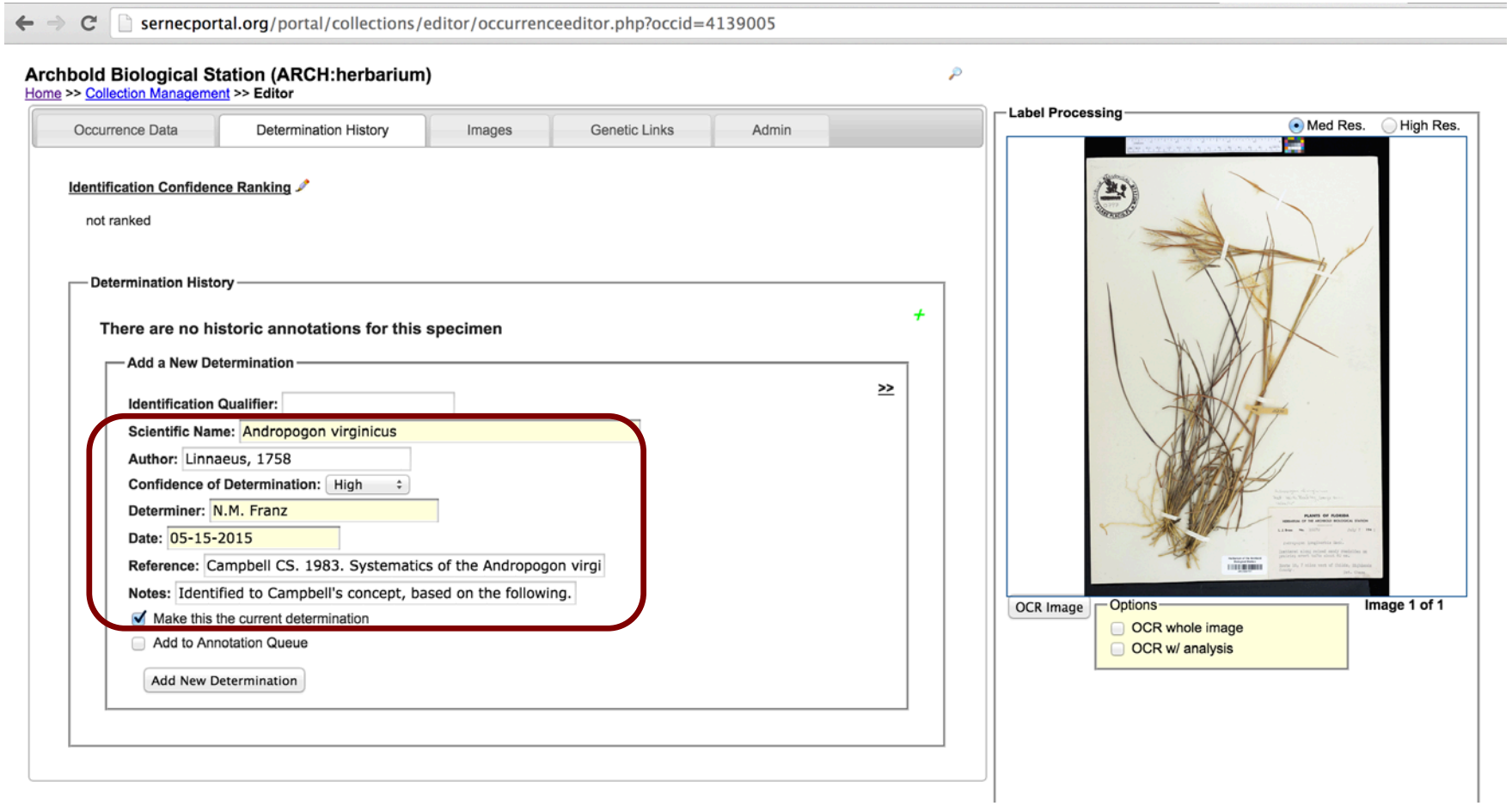
Step 7. Upgrade voucher identifications to taxonomic concept labels

- This is **likely the most challenging** and least well understood of all needed steps.
- Combinations of human input and 'smart inferences' might cover much ground.



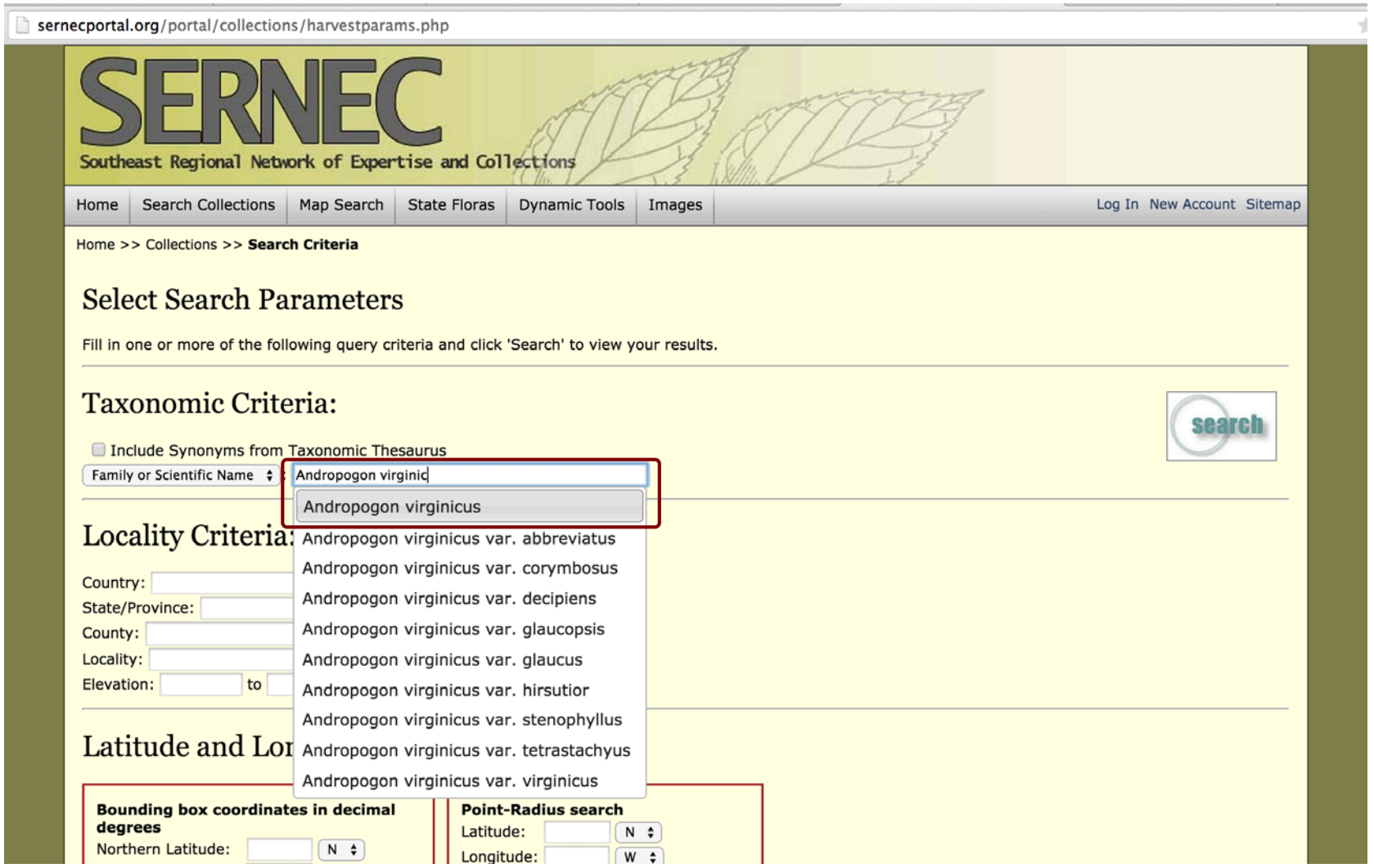
Step 7. Upgrade voucher identifications to taxonomic concept labels

☐Environment can support **occurrence-to-taxonomic-concept-label identifications.**

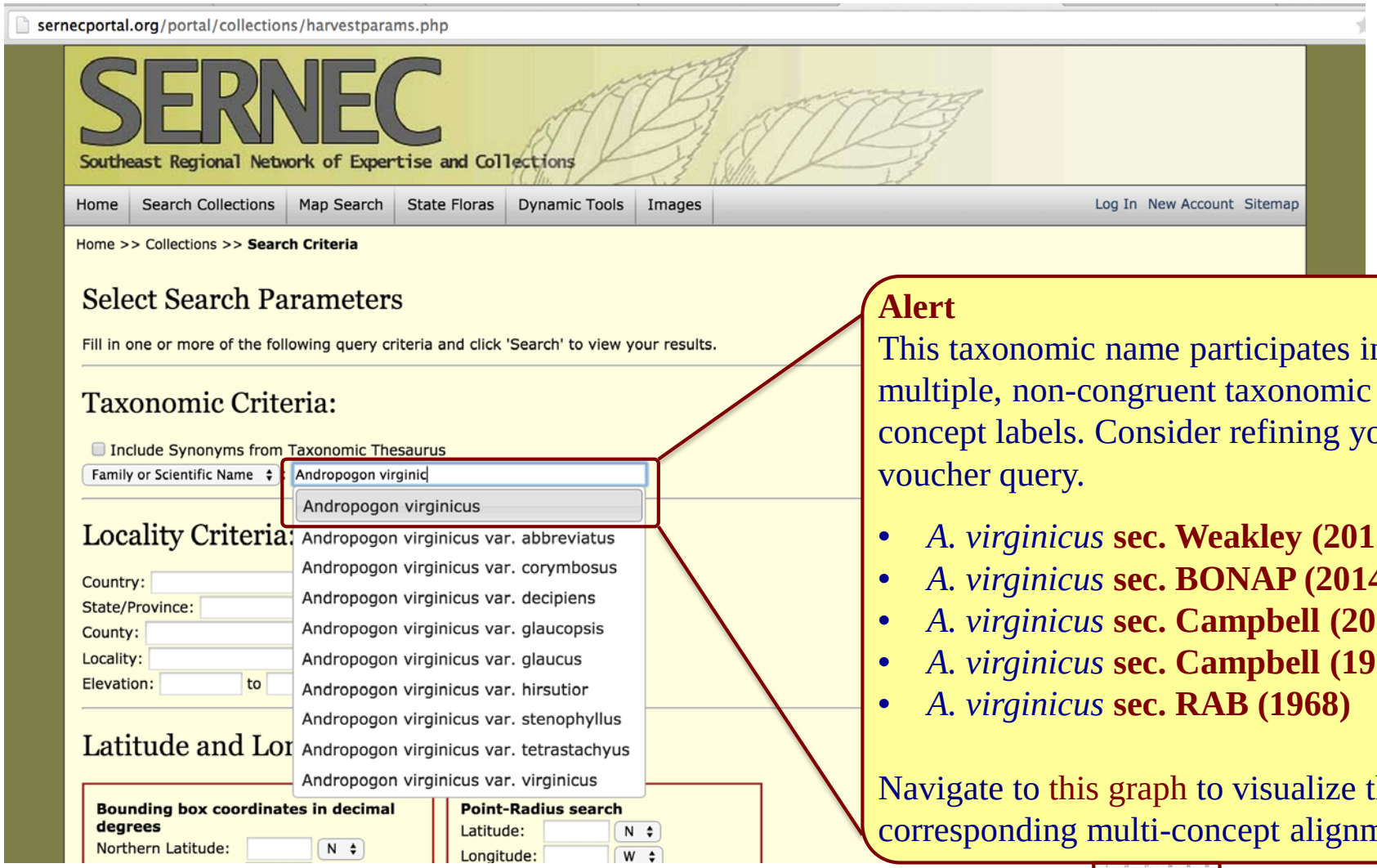


Putting it all together.

Step 8. Support concept-level queries and query products



Step 8. Support concept-level queries and query products



Alert

This taxonomic name participates in multiple, non-congruent taxonomic concept labels. Consider refining your voucher query.

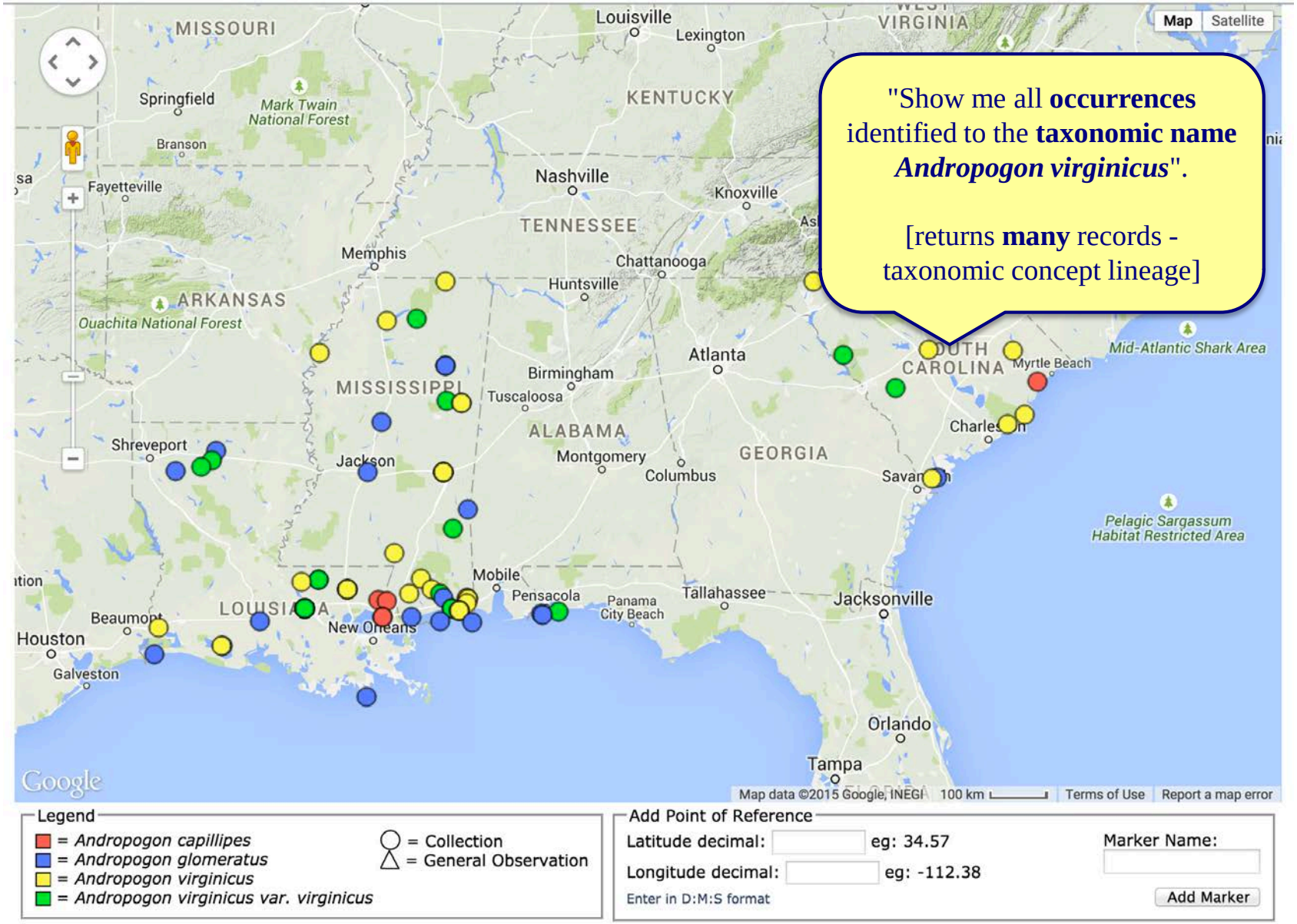
- *A. virginicus* **sec. Weakley (2015)**
- *A. virginicus* **sec. BONAP (2014)**
- *A. virginicus* **sec. Campbell (2003)**
- *A. virginicus* **sec. Campbell (1983)**
- *A. virginicus* **sec. RAB (1968)**

Navigate to this graph to visualize the corresponding multi-concept alignment.

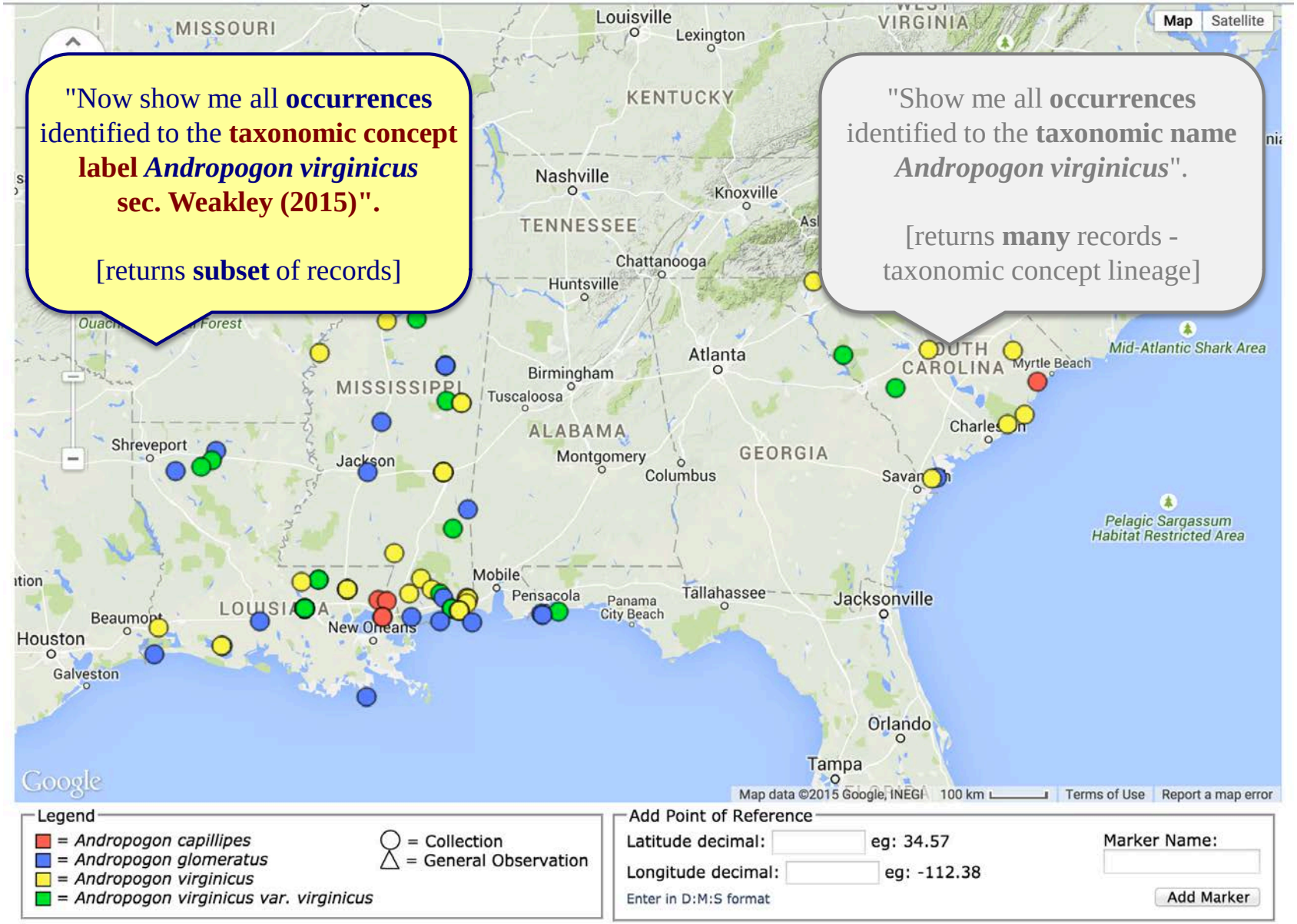
Now ready to do science?

Yes, we think so.

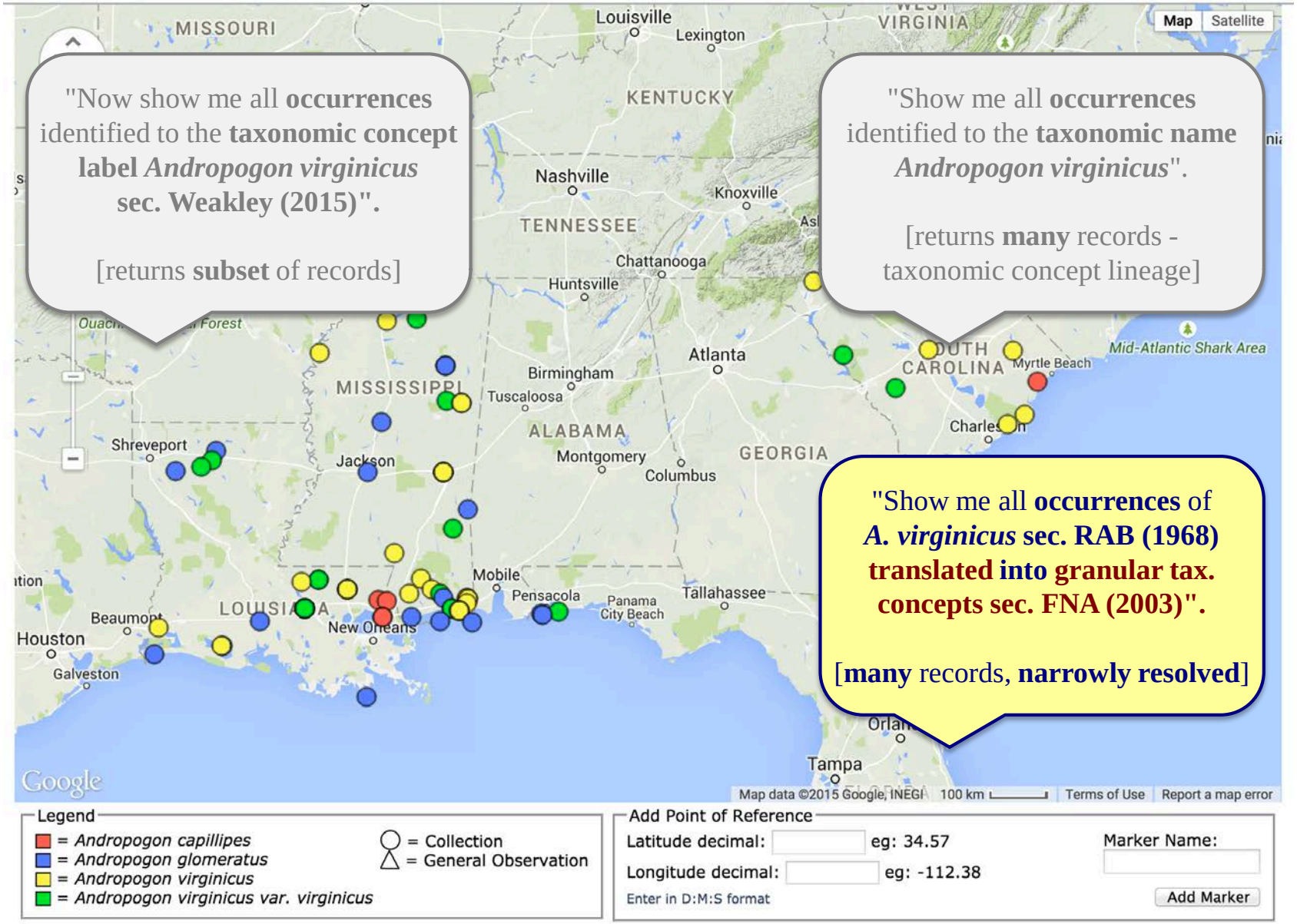
Step 8. Support concept-level queries and query products



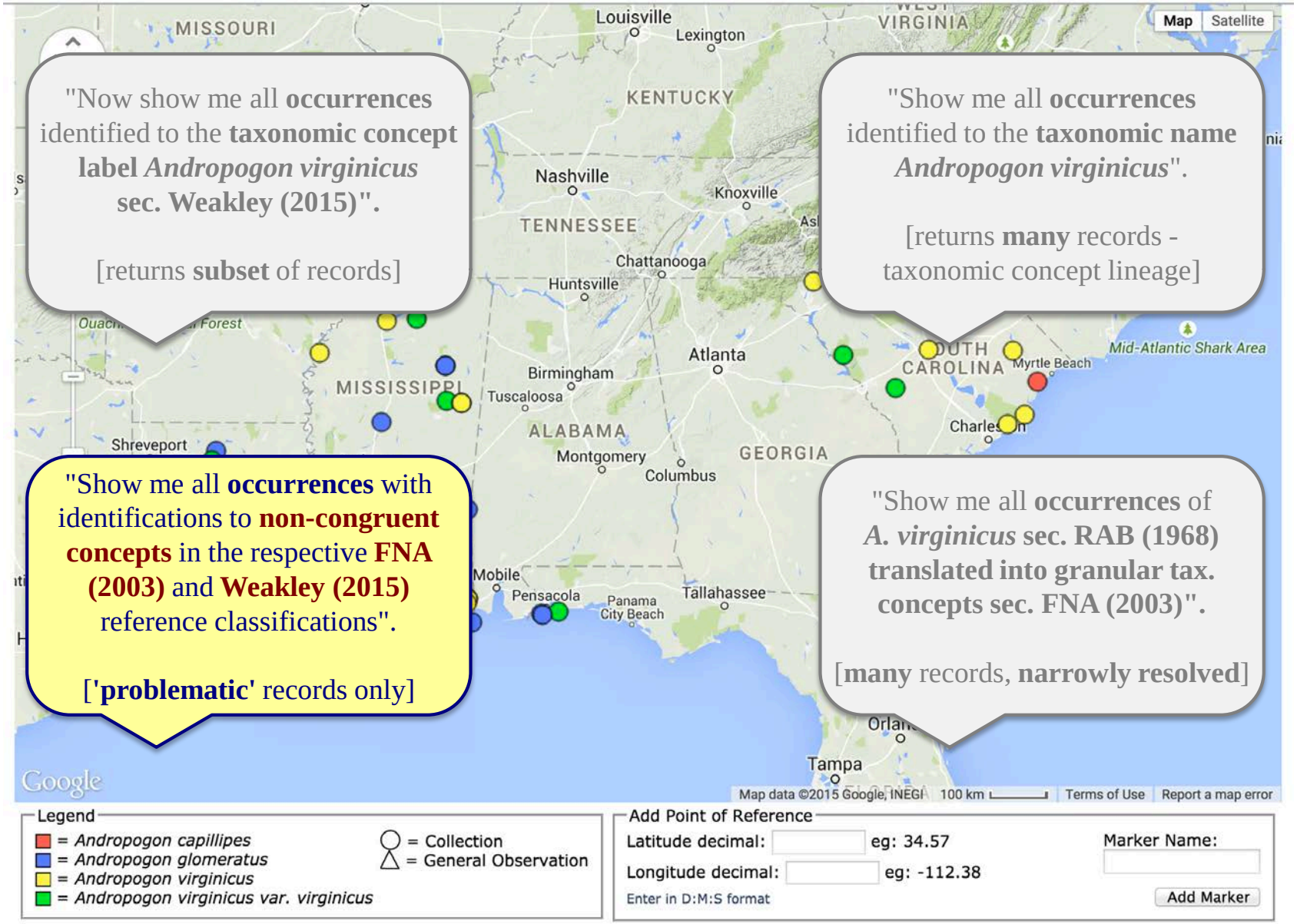
Step 8. Support concept-level queries and query products



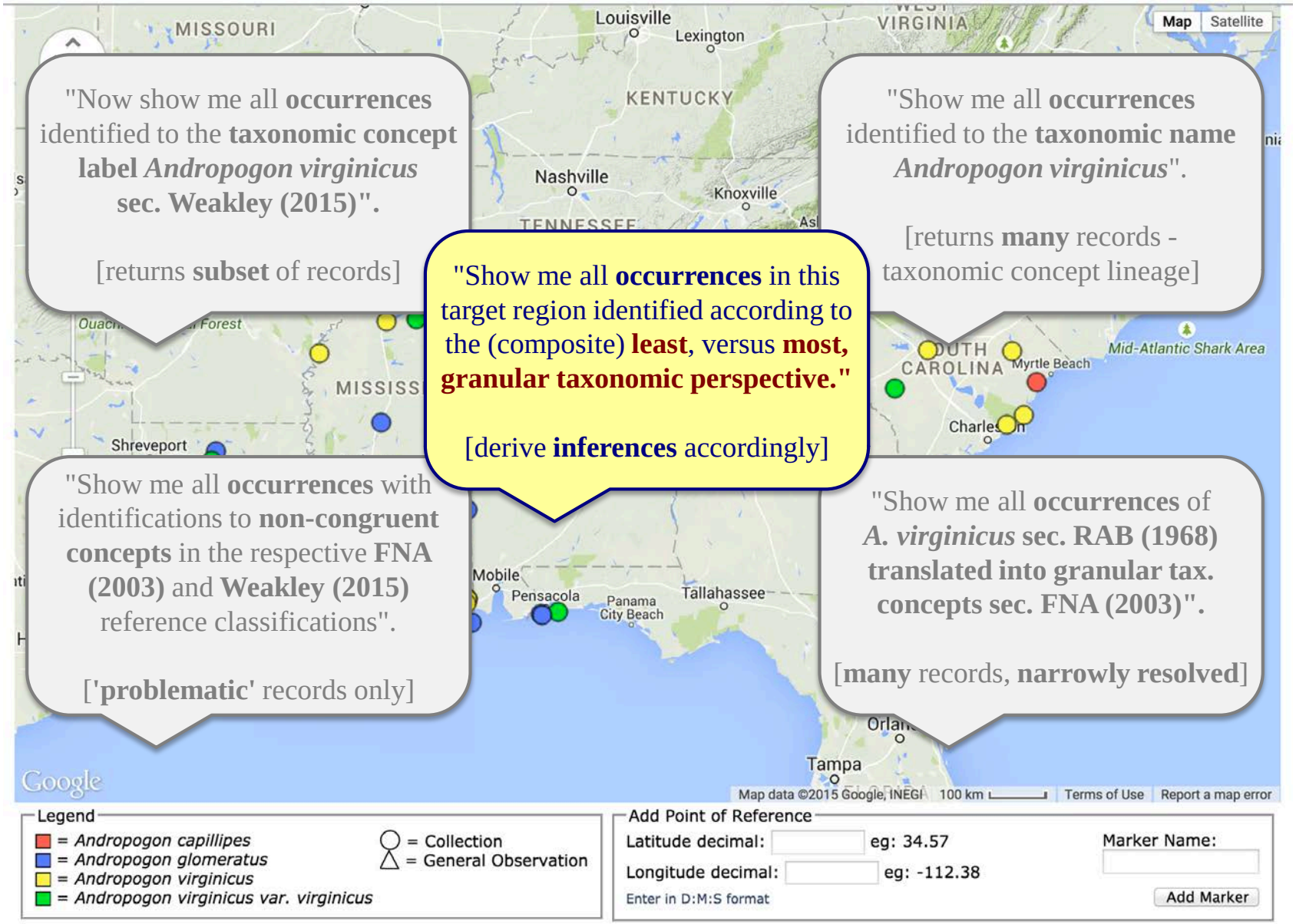
Step 8. Support concept-level queries and query products



Step 8. Support concept-level queries and query products



Step 8. Support concept-level queries and query products



So, we think this is doable.

Review of steps and feasibility / outlook (SERNEC = test case?)

Step #	Circumscription of task	Status (May 2015)
1	Diagnose the opportunity for **better semantics**	**Complete** (enough)
2	Individuate names as **taxonomic concept labels**	**Complete** (for East U.S. Flora)

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3	Semantically represent **taxonomic concept provenance**	**Well advanced** (Weakley Flora)
4	Infer logically consistent **concept taxonomy alignments**	**Well advanced** (Weakley Flora)
5	**Visualize alignments** and related products (MIR)	**Well advanced** (Weakley Flora)

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5	**Visualize alignments** and related products (MIR)	**Well advanced** (Weakley Flora)
6	Add concept-level semantics to **portal infrastructure**	**Doable, incomplete** (Symbiota)
7	**Voucher identifications to taxonomic concept labels**	**To be developed** (humans, logic)
8	**Support concept-level queries and query products**	**Needs completion of steps 6-7**

Access to evolving taxonomic content

Ownership of new taxonomic theory production

Will it matter?

User control in configuring "the taxonomic variable".

Taxonomy access, ownership, control **TRUST.**

Access to evolving taxonomic content

Ownership of new taxonomic theory production

We should be very curious about,

and try to answer, that question.

User control in configuring "the taxonomic variable".

Taxonomy access, ownership, control
 TRUST.

Acknowledgments

- **Euler/X team:** Mingmin Chen, Parisa Kianmajd, Shizhuo Yu, Shawn Bowers & Bertram Ludäscher.
- **ETC team:** Hong Cui, James Macklin, Thomas Rodenhausen.
- **PathwayMatrix:** Tuan Nhon Dang.
- **NSF** DEB–1155984, DBI–1342595 (Franz); IIS–118088, DBI–1147273 (Ludäscher); DBI–1410069 / 1410439 (Murrell / Weakley).

- **Information** @ http://taxonbytes.org/tag/concept-taxonomy/
- **Euler/X code** @ https://bitbucket.org/eulerx
- **Symbiota.org** @ http://symbiota.org/

http://taxonbytes.org/

http://biokic.asu.edu (in dev.)

The Euler/X taxonomic alignment approach explained

journals.plos.org/plosone/article?id=10.1371/journal.pone.0118247

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RESEARCH ARTICLE

http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0118247

Reasoning over Taxonomic Change: Exploring Alignments for the *Perelleschus* Use Case

Nico M. Franz, Mingmin Chen, Shizhuo Yu, Parisa Kianmajd, Shawn Bowers, Bertram Ludäscher

Published: February 20, 2015 • DOI: 10.1371/journal.pone.0118247

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Discussion
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Abstract

Classifications and phylogenetic inferences of organismal groups change in light of new insights. Over time these changes can result in an imperfect tracking of taxonomic perspectives through the re-/use of Code-compliant or informal names. To mitigate these limitations, we introduce a novel approach for aligning taxonomies through the interaction of human experts and logic reasoners. We explore the performance of this approach with the *Perelleschus* use case of Franz & Cardona-Duque (2013). The use case includes six taxonomies published from 1936 to 2013, 54 taxonomic concepts (i.e., circumscriptions of names individuated according to their respective source publications), and 75 expert-asserted Region Connection Calculus articulations (e.g., congruence, proper inclusion, overlap, or exclusion). An Open Source reasoning toolkit is used to analyze 13 paired *Perelleschus* taxonomy alignments under heterogeneous constraints and interpretations. The reasoning workflow optimizes the logical consistency and expressiveness of the input and infers the set of maximally informative relations among the entailed taxonomic concepts. The latter are then used to produce merge visualizations that represent all congruent and non-congruent taxonomic elements among the aligned input trees. In this small use case with 6-53 input concepts per alignment, the information gained through the reasoning process is on average one order of magnitude greater than in the input. The approach offers scalable solutions for tracking provenance among succeeding taxonomic perspectives that may have differential biases in naming conventions, phylogenetic resolution, ingroup and outgroup sampling, or ostensive (member-referencing) versus intensional (property-referencing) concepts and articulations.

Subject Areas

Taxonomy
Phylogenetics
Reasoning
Graphs
Ontologies
Multiple alignment c...
Phylogenetic analysis
Biodiversity

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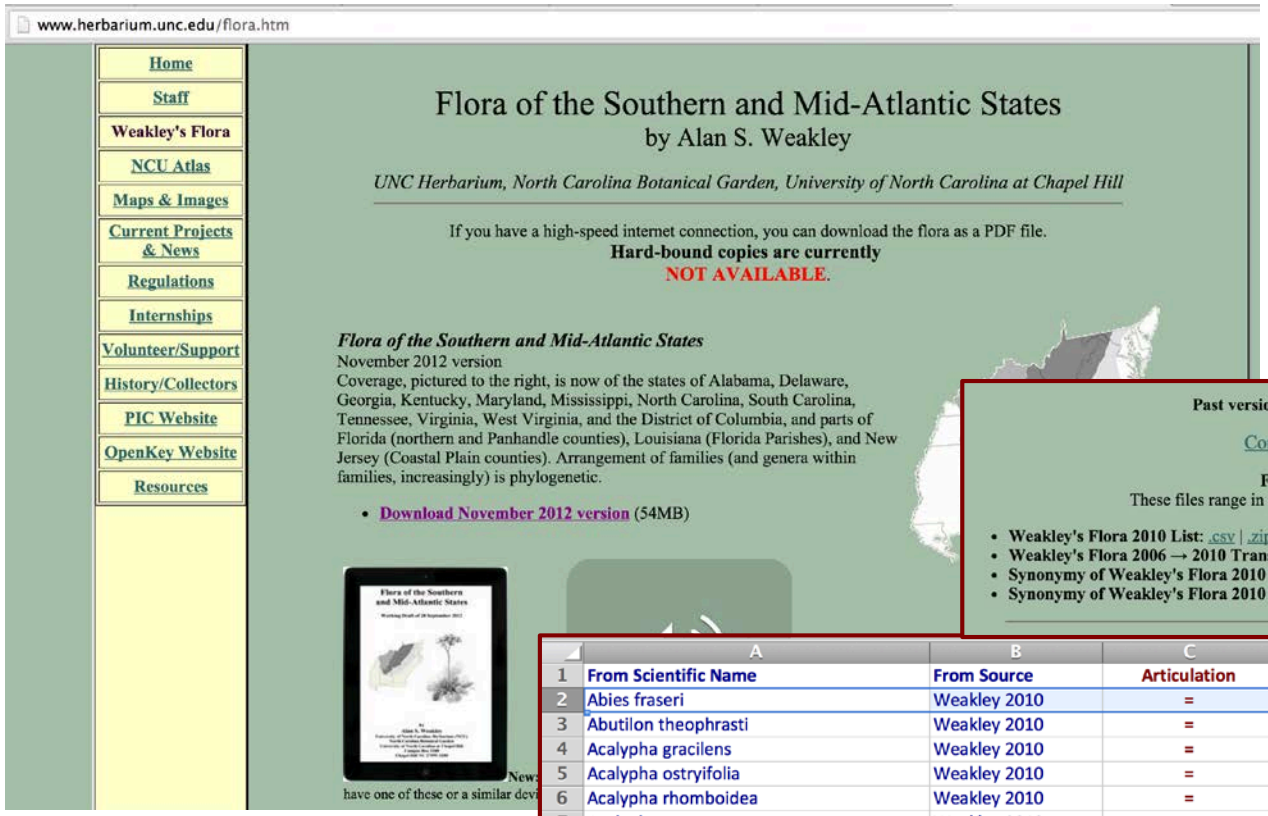
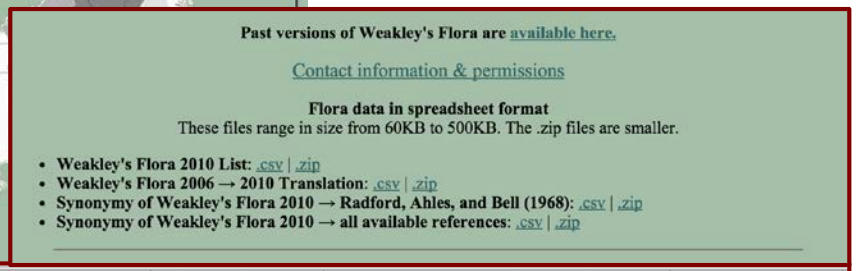
Select references on **concept taxonomy** and the **Euler/X toolkit**

- **Franz *et al.* 2008.** On the use of taxonomic concepts in support of biodiversity research and taxonomy. In: The New Taxonomy; pp. 63–86. Link
- **Franz & Peet. 2009.** Towards a language for mapping relationships among taxonomic concepts. Systematics and Biodiversity 7: 5–20. Link
- **Franz & Thau. 2010.** Biological taxonomy and ontology development: Scope and limitations. Biodiversity Informatics 7: 45–66. Link
- **Chen *et al.* 2014.** Euler/X: a toolkit for logic-based taxonomy integration. WFLP 2013 – 22nd International Workshop on Functional and (Constraint) Logic Programming. Link
- **Chen *et al.* 2014.** A hybrid diagnosis approach combining Black-Box and White-Box reasoning. Lecture Notes in Computer Science 8620: 127–141. Link
- **Franz *et al.* 2015.** Names are not good enough: Reasoning over taxonomic change in the *Andropogon* complex. Semantic Web – Interoperability, Usability, Applicability – Special Issue on Semantics for Biodiversity. (in press) Link
- **Franz *et al.* 2015.** Reasoning over taxonomic change: Exploring alignments for the Perelleschus use case. PLoS ONE 10(2): e0118247. Link
- **Franz *et al.* 2015.** Taxonomic provenance: Two influential primate classifications logically aligned. (in review) Link

Miscellaneous appended slides

Weakley's 2010 Flora and > 60k concept-to-concept articulations

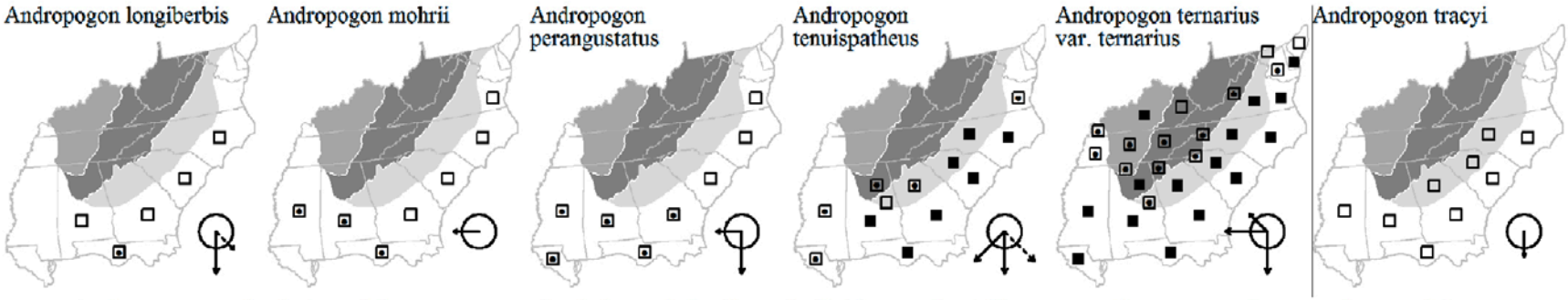




	A	B	C	D	E
1	From Scientific Name	From Source	Articulation	To Scientific Name	To Source
2	Abies fraseri	Weakley 2010	=	Abies fraseri	RAB
3	Abutilon theophrasti	Weakley 2010	=	Abutilon theophrastii	RAB
4	Acalypha gracilens	Weakley 2010	=	Acalypha gracilens	RAB
5	Acalypha ostryifolia	Weakley 2010	=	Acalypha ostryaefolia	RAB
6	Acalypha rhomboidea	Weakley 2010	=	Acalypha rhomboidea	RAB
7	Acalypha setosa	Weakley 2010	=	Acalypha setosa	RAB
8	Acalypha virginica	Weakley 2010	=	Acalypha virginica	RAB
9	Acanthospermum australe	Weakley 2010	=	Acanthospermum australe	RAB
10	Acer floridanum	Weakley 2010	=	Acer saccharum ssp. floridanum	RAB
11	Acer leucoderme	Weakley 2010	=	Acer saccharum ssp. leucoderme	RAB
12	Acer negundo var. negundo	Weakley 2010	<	Acer negundo	RAB
13	Acer negundo var. texanum	Weakley 2010	<	Acer negundo	RAB
14	Acer nigrum	Weakley 2010	=	Acer saccharum ssp. nigrum	RAB
15	Acer pensylvanicum	Weakley 2010	=	Acer pensylvanicum	RAB
16	Acer rubrum var. drummondii	Weakley 2010	<	Acer rubrum	RAB
17	Acer rubrum var. rubrum	Weakley 2010	<	Acer rubrum	RAB
18	Acer rubrum var. trilobum	Weakley 2010	<	Acer rubrum	RAB
19	Acer saccharinum	Weakley 2010	=	Acer saccharinum	RAB
20	Acer saccharum	Weakley 2010	=	Acer saccharum ssp. saccharum	RAB

Source: http://www.herbarium.unc.edu/flora.htm

Excerpt from Weakley's (2012) concept-level Flora



Andropogon virginicus Linnaeus *var.* ***decipiens*** C.S. Campbell, Deceptive Bluestem. Savannas, flatwoods, maritime wet grasslands, disturbed pinelands. September-October. Se. VA south to s. FL and west to w. FL; also in the Bahamas (Sorrie & LeBlond (1997). [= FNA, K, Z (1986); < *A. virginicus* – RAB, S; < *A. virginicus* var. *virginicus* – F, G, HC; = *A. virginicus* var. *virginicus* – Z (1983 – "deceptive variant")]

Andropogon virginicus Linnaeus *var.* ***virginicus***, Old-field Broomstraw, Broomsedge, "Sedge Grass", "Sage Grass". Old fields, roadbanks, disturbed sites. September-October. MA west to MI and e. KA, south to FL and e. TX, and in the Caribbean and Central America. Campbell (1983) recognized 3 "variants" within *A. virginicus* var. *virginicus*; the "deceptive variant" he later (1986) described formally as var. *decipiens* (see above). The "old-field variant" is the common "variant" in our area, occurring abundantly throughout the state. It has green stem internodes and the leaves usually pubescent, at least on the margins near the collar. The "smooth variant" is known only from the Coastal Plain and is apparently rare in our area, known from NC and SC (Berkeley and Marion counties; P. McMillan, pers. comm.) southward and westward. It has glaucous stem internodes and glabrous leaves. The "smooth variant" probably warrants formal taxonomic recognition. [= FNA, K, Z ("oldfield variant" and "smooth variant"); < *A. virginicus* – RAB, Pa, S, W; < *A. virginicus* var. *virginicus* – C, WV; < *A. virginicus* var. *virginicus* – G, HC (also see var. *decipiens*); >< *A. virginicus* var. *virginicus* – F; > *A. virginicus* var. *tetrastachyus* (Elliott) Hackel – F]

Alan Weakley 2014 (UNC Herbarium) - *Magnolia* concept evolution

Taxonomically Useful Finest Unit (TUFU)	TUFU A	TUFU B	TUFU C	TUFU D	TUFU E	TUFU F	TUFU G	TUFU H	TUFU I	TUFU J	TUFU K	Originator of Taxschema
Informal tag name	*Magnolia acuminata*	*Magnolia "cordata"*	*Magnolia virginiana var. australis*	*Magnilia virginiana "ambiguous"*	*Magnolia virginiana var. virginiana*	*Magnolia grandiflora*	*Magnolia ashei*	*Magnolia macrophylla*	*Magnolia fraseri*	*Magnolia pyramidata*	*Magnolia tripetala*	
basionym	*Magnolia acuminata var. acuminata* Linnaeus 1759	*Tulipastrum americanum var. subcordatum* Spach 1839	*Magnolia virginiana var. australis* Sargent 1919	*Magnolia virginiana* Linnaeus 1753	*Magnolia virginiana* Linnaeus 1753	*Magnolia grandiflora* Linnaeus 1759	*Magnolia ashei* Weatherby 1926	*Magnolia macrophylla* Michaux 1803	*Magnolia fraseri* Walter 1788	*Magnolia pyramidata* W. Bartram 1791	*Magnolia virginiana var. tripetala Linnaeus 1759*	
Taxschema 12	*Magnolia acuminata var. acuminata*	*Magnolia acuminata var. subcordata*	*Magnolia virginiana var. australis*	*Magnolia virginiana var. virginiana*		*Magnolia grandiflora*	*Magnolia ashei*	*Magnolia macrophylla*	*Magnolia fraseri*	*Magnolia pyramidata*	*Magnolia tripetala*	Weakley 2014
Taxschema 11	*Yulania acuminata*		*Magnolia virginiana*			*Magnolia grandiflora*	*Metamagnolia macrophylla ssp. ashei* (Weatherby) Spongberg	*Metamagnolia macrophylla ssp. macrophylla*	*Paramagnolia fraseri var. fraseri*	*Paramagnolia fraseri var. pyramidata*	*Houpoea tripetala*	Sima & Lu 2012
Taxschema 10	*Magnolia acuminata*		*Magnolia virginiana*			*Magnolia grandiflora*	*Magnolia macrophylla var. ashei* (Weatherby) D.L. Johnson	[not in area of coverage]: implied name = Magnolia macrophylla var. macrophylla	[not in area of coverage]: implied name = Magnolia fraseri	*Magnolia pyramidata*	*Magnolia tripetala*	Wunderlin & Hansen 2011
Taxschema 9	[not treated]	[not treated]	*Magnolia virginiana ssp. australis*	*Magnolia virginiana ssp. virginiana*		[not treated]	[not treated]	[not treated]	[not treated]	[not treated]	[not treated]	Palmarola-Bejerano, Romanov, & Bobrov 2008
Taxschema 8	*Magnolia acuminata var. acuminata*	*Magnolia acuminata var. subcordata*	*Magnolia virginiana ssp. australis*	*Magnolia virginiana ssp. virginiana*		*Magnolia grandiflora*	*Magnolia macrophylla ssp. ashei*	*Magnolia macrophylla ssp. macrophylla*	Magnolia fraseri var. pyramidata	Magnolia fraseri var. fraseri	*Magnolia tripetala*	Spongberg 1998
Taxschema 7	*Magnolia acuminata var. acuminata*	*Magnolia acuminata var. subcordata*	*Magnolia virginiana var. australis*	*Magnolia virginiana var. virginiana*		*Magnolia grandiflora*	*Magnolia macrophylla ssp. ashei*	*Magnolia macrophylla ssp. macrophylla*	*Magnolia fraseri ssp. pyramidata*	*Magnolia fraseri ssp. fraseri*	*Magnolia tripetala*	Tobe 1998
Taxschema 6	*Magnolia acuminata*		*Magnolia virginiana*			*Magnolia grandiflora*	*Magnolia ashei*	*Magnolia macrophylla*	*Magnolia fraseri*	*Magnolia pyramidata*	*Magnolia tripetala*	Meyer in FNA 1997
Taxschema 5	*Magnolia acuminata*		*Magnolia virginiana*			*Magnolia grandiflora*	[not in area of coverage]	*Magnolia macrophylla*	*Magnolia fraseri*	[not in area of coverage]	*Magnolia tripetala*	Cronquist 1991
Taxschema 4	*Magnolia acuminata*		*Magnolia virginiana*			*Magnolia grandiflora*	[not in area of coverage]	*Magnolia macrophylla*	*Magnolia fraseri*	*Magnolia pyramidata*	*Magnolia tripetala*	Radford, Ahles, & Bell 1968
Taxschema 3	*Magnolia acuminata*	[not in area of coverage]	*Magnolia virginiana var. australis*		*Magnolia virginiana var. virginiana*	[not regarded as naturalized]	[not in area of coverage]	*Magnolia macrophylla*	*Magnolia Fraseri*	[not in area of coverage]	*Magnolia tripetala*	Fernald 1950
Taxschema 2	*Tulipastrum acuminatum*	*Tulipastrum cordatum*	*Magnolia virginiana*			*Magnolia grandiflora*	*Magnolia Ashei*	*Magnolia macrophylla*	*Magnolia Fraseri*	*Magnolia pyramidata*	*Magnolia tripetala*	Small 1933
Taxschema 1	*Magnolia acuminata*	*Magnolia cordata*	*Magnolia glauca*			*Magnolia grandiflora*	*Magnolia macrophylla*		*Magnolia Fraseri*		*Magnolia Umbrella*	Chapman 1883

The other piece in the puzzle: **Concept-to-voucher identifications**

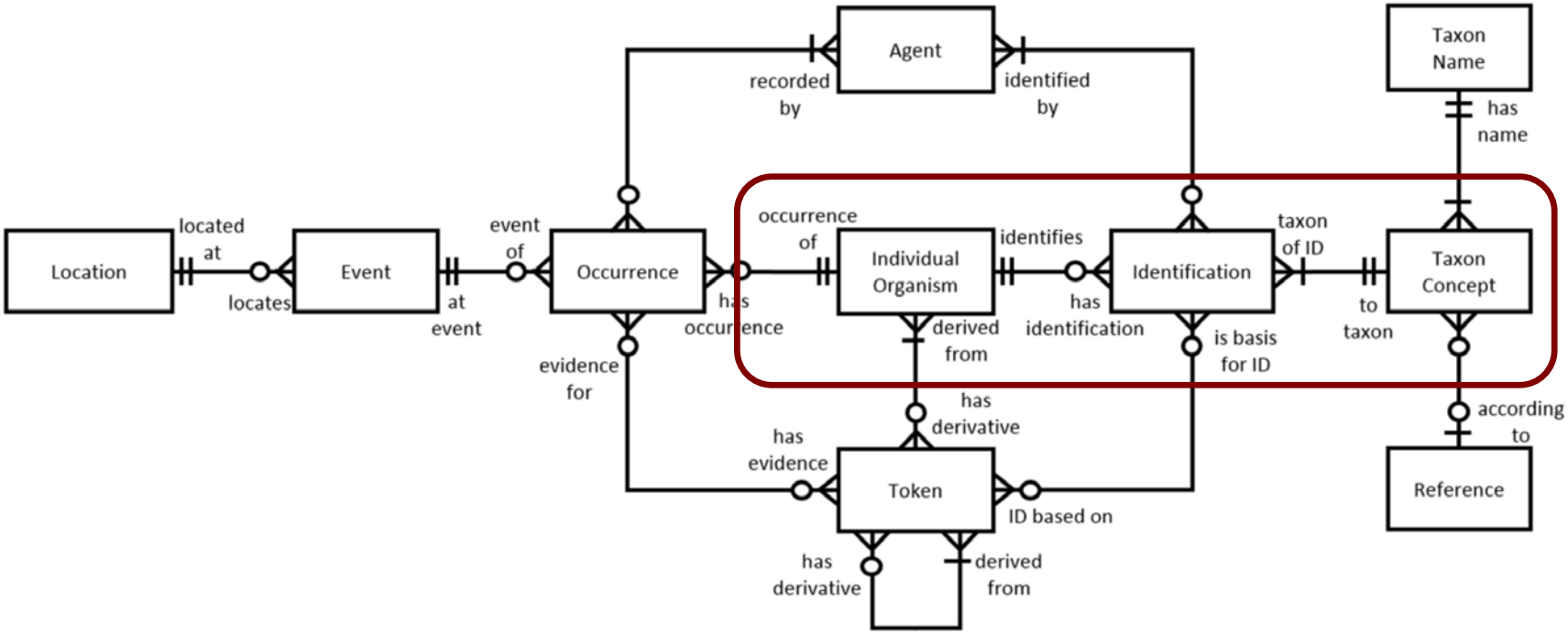
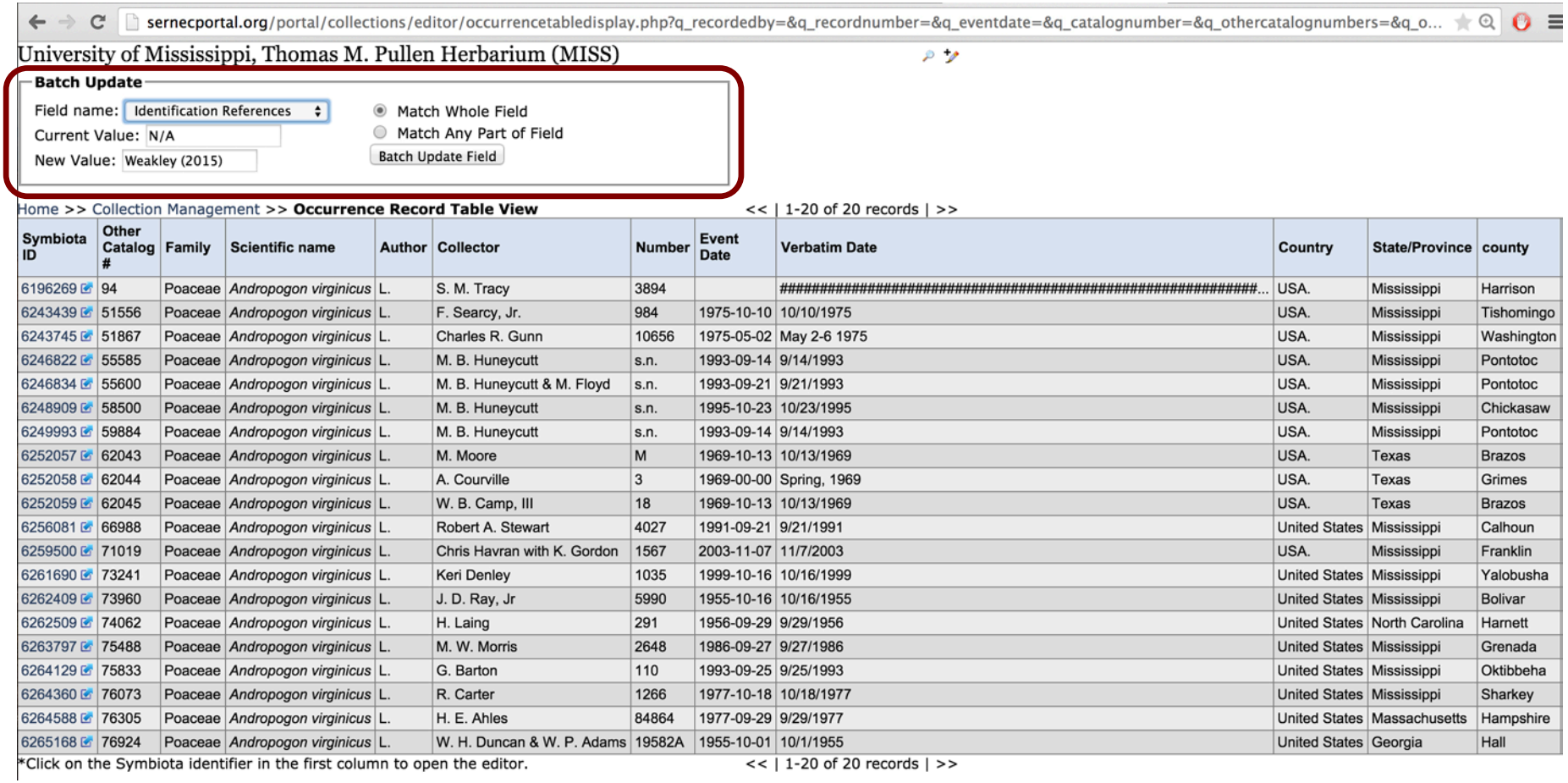


Fig. 1. Entity-relationship diagram of the Darwin-SW model using crow's foot notation with classes and relationships described in English text

Source: Baskauf & Webb. 2014. Darwin-SW. URL: http://www.semantic-web-journal.net/system/files/swj635.pdf

SERNEC - batch editing data - upgrade identification references



Symbiota ID	Other Catalog #	Family	Scientific name	Author	Collector	Number	Event Date	Verbatim Date	Country	State/Province	county
6196269	94	Poaceae	*Andropogon virginicus*	L.	S. M. Tracy	3894		##########	USA.	Mississippi	Harrison
6243439	51556	Poaceae	*Andropogon virginicus*	L.	F. Searcy, Jr.	984	1975-10-10	10/10/1975	USA.	Mississippi	Tishomingo
6243745	51867	Poaceae	*Andropogon virginicus*	L.	Charles R. Gunn	10656	1975-05-02	May 2-6 1975	USA.	Mississippi	Washington
6246822	55585	Poaceae	*Andropogon virginicus*	L.	M. B. Huneycutt	s.n.	1993-09-14	9/14/1993	USA.	Mississippi	Pontotoc
6246834	55600	Poaceae	*Andropogon virginicus*	L.	M. B. Huneycutt & M. Floyd	s.n.	1993-09-21	9/21/1993	USA.	Mississippi	Pontotoc
6248909	58500	Poaceae	*Andropogon virginicus*	L.	M. B. Huneycutt	s.n.	1995-10-23	10/23/1995	USA.	Mississippi	Chickasaw
6249993	59884	Poaceae	*Andropogon virginicus*	L.	M. B. Huneycutt	s.n.	1993-09-14	9/14/1993	USA.	Mississippi	Pontotoc
6252057	62043	Poaceae	*Andropogon virginicus*	L.	M. Moore	M	1969-10-13	10/13/1969	USA.	Texas	Brazos
6252058	62044	Poaceae	*Andropogon virginicus*	L.	A. Courville	3	1969-00-00	Spring, 1969	USA.	Texas	Grimes
6252059	62045	Poaceae	*Andropogon virginicus*	L.	W. B. Camp, III	18	1969-10-13	10/13/1969	USA.	Texas	Brazos
6256081	66988	Poaceae	*Andropogon virginicus*	L.	Robert A. Stewart	4027	1991-09-21	9/21/1991	United States	Mississippi	Calhoun
6259500	71019	Poaceae	*Andropogon virginicus*	L.	Chris Havran with K. Gordon	1567	2003-11-07	11/7/2003	USA.	Mississippi	Franklin
6261690	73241	Poaceae	*Andropogon virginicus*	L.	Keri Denley	1035	1999-10-16	10/16/1999	United States	Mississippi	Yalobusha
6262409	73960	Poaceae	*Andropogon virginicus*	L.	J. D. Ray, Jr	5990	1955-10-16	10/16/1955	United States	Mississippi	Bolivar
6262509	74062	Poaceae	*Andropogon virginicus*	L.	H. Laing	291	1956-09-29	9/29/1956	United States	North Carolina	Harnett
6263797	75488	Poaceae	*Andropogon virginicus*	L.	M. W. Morris	2648	1986-09-27	9/27/1986	United States	Mississippi	Grenada
6264129	75833	Poaceae	*Andropogon virginicus*	L.	G. Barton	110	1993-09-25	9/25/1993	United States	Mississippi	Oktibbeha
6264360	76073	Poaceae	*Andropogon virginicus*	L.	R. Carter	1266	1977-10-18	10/18/1977	United States	Mississippi	Sharkey
6264588	76305	Poaceae	*Andropogon virginicus*	L.	H. E. Ahles	84864	1977-09-29	9/29/1977	United States	Massachusetts	Hampshire
6265168	76924	Poaceae	*Andropogon virginicus*	L.	W. H. Duncan & W. P. Adams	19582A	1955-10-01	10/1/1955	United States	Georgia	Hall