Systematic and Comparative Biology

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"There have been many authorities who have asserted that the basis of science lies in counting or measuring, i.e. in the use of mathematics. Neither counting nor measuring can however be the most fundamental process in our study of the material universe - before you can do either to any purpose you must first select what you propose to count or measure, *which presupposes a classification*."

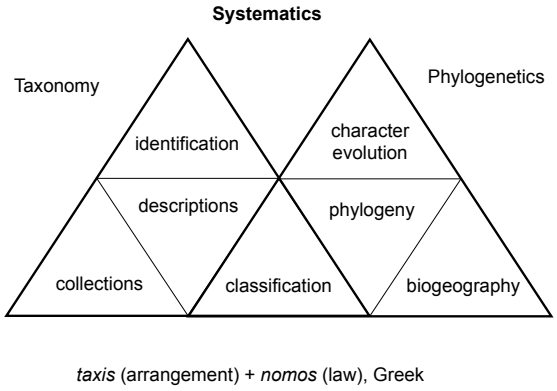
R. A. Crowson 1970 Classification and Biology (p.2) [italics added]

Lecture 1: Introduction to Biological Systematics

Outline: The role and value of Systematics

Taxonomy (α taxonomy)
- Describing species
- Identification, Classification
- Collections, Conservation

Phylogenetics (β taxonomy)
- Phylogeny
- Classification (?)
- Evolutionary processes / patterns
- Conservation



taxis (arrangement) + *nomos* (law), Greek

Systematics

In short:

Discover what is "out there"

and

Fit it to the tree of life

α (alpha) taxonomy

- Describing species
  (what are "species"?)
- "mapping biodiversity"
- Finding "new" species, new traits
- Originally to distinguish beneficial from harmful organisms

α (alpha) taxonomy

- ca. 1.5 - 1.75 million species named
- Not sure, no single list / database
- ca. 10-15k new species named / year
- ca. 5-15 million awaiting description
- ca. 500-1500 years, *at this rate*

Kingdom Animalia

Known species

~1.03 million animal species

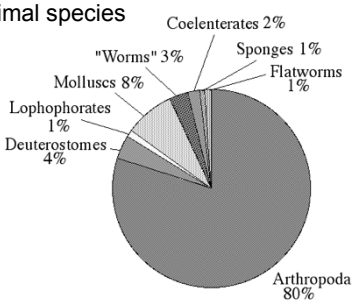
96% of animal species are invertebrates

80% of animal species are Arthropods

73% of animal species are Insects

All life: ~1,413,000 spp

53% of all living species are insects



Species Richness - Estimation

Erwin, Terry, L. 1982. Tropical forests: Their richness in Coleoptera and other arthropod species. Coleopterists Bulletin 36:74-75.

- extrapolation from data about canopy insects
- one hectare ~ 41,000 spp*
- global ~ 30,000,000 !

(not 1.5 million)

- hypothesis proposed, not a claim

*Canada: 30,000 insect spp

(55,000 est. total)

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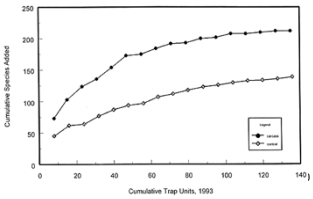
Species Richness - Estimation

Erwin, Terry, L. 1982. Tropical forests: Their richness in Coleoptera and other arthropod species. Coleopterists Bulletin 36:74-75.

Is 30,000,000 a reasonable estimate?

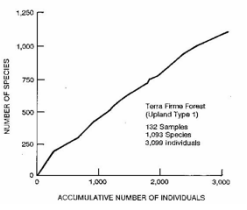
Erwin argues yes - based in part on the rule of diminishing returns…



Species Richness - Estimation

Erwin, Terry, L. 1982. Tropical forests: Their richness in Coleoptera and other arthropod species. Coleopterists Bulletin 36:74-75.

New species found will eventually plateau - but Erwin's samples haven't yet



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α (alpha) taxonomy

- Description of nature (basic / pure, research)
- Same pursuit as the cataloging of astronomical bodies like stars, planets, galaxies, etc.
- Exciting! (usually)

α (alpha) taxonomy

- Character states that are **unique**
- Character states that are **shared**
  = suggest relationships
  = *phylogenetics*

α (alpha) taxonomy

- Develop a system of **names**
- Names at & above species level: Classifications
- Ideal: **stable** and **universal** language
- *Names are primary anchors for information storage & retrieval*

Introduced Predators Transform Subarctic Islands from Grassland to Tundra

D. A. Croll,[1]* J. L. Maron,[2] J. A. Estes,[1,3] E. M. Danner,[1] G. V. Byrd[4]

Top predators often have powerful direct effects on prey populations, but whether these direct effects propagate to the base of terrestrial food webs is debated. There are few examples of trophic cascades strong enough to alter the abundance and composition of entire plant communities. We show that the introduction of arctic foxes (*Alopex lagopus*) to the Aleutian archipelago induced strong shifts in plant productivity and community structure via a previously unknown pathway. By preying on seabirds, foxes reduced nutrient transport from ocean to land, affecting soil fertility and transforming grasslands to dwarf shrub/forb–dominated ecosystems.

Nearly half a century ago, Hairston *et al.* (*1*) proposed that plant productivity and composition were influenced by apex predators through cascading trophic interactions. According to their "Green World" view, the direct effects of predators on herbivore populations transcend multiple trophic levels indirectly to enhance plant community productivity and biomass. Despite great progress in food web ecology, the indirect effects of top predators on vegetation dynamics in terrestrial systems remain unresolved and actively debated (*2*–*6*). Compelling demonstrations of multitrophic predator impacts on entire plant communities are scarce, in part because the spatial and temporal scales necessary to perform the appropriate community-wide experiments are daunting.

The introduction of predators to islands provides an opportunity to explore the indirect effects of predators on vegetation. Introduced predators commonly have devastating direct effects on their prey (*7*). The histories of these introductions are often well known, and the relative simplicity and isolation of insular systems facilitate the study of whole-community responses. Here we investigate how the introduction of arctic foxes (*Alopex lagopus*) to the Aleutian archipelago affected terrestrial ecosystems across this 1900-km island chain.

The Aleutian archipelago is a remote series of physically similar volcanic islands extending westward from the Alaska Peninsula (Fig. 1). The archipelago currently supports 29 species of breeding seabirds, together numbering >10 million individuals (*8*). Seabirds deliver nutrient-rich guano from productive ocean waters (*9*) to the nutrient-limited plant communities (*10*, *11*). Historically, seabirds inhabited most islands along the Aleutian chain. Following the collapse of the maritime fur trade in the late 19th and early 20th centuries, foxes were introduced to >400 Alaskan islands as an additional fur source (*12*). The introduced foxes severely reduced local avifaunas, especially seabirds (*13*). However, several islands remained fox free, either because introductions failed or were not undertaken (*12*–*14*). Hence, a large-scale natural experiment to evaluate the effects of exotic predators on insular ecosystems was unwittingly initiated more than a century ago. We use this experiment to show how differing seabird densities on islands with and without foxes affect soil and plant nutrients; plant abundance, composition, and productivity; and nutrient flow to higher trophic levels. These determinations

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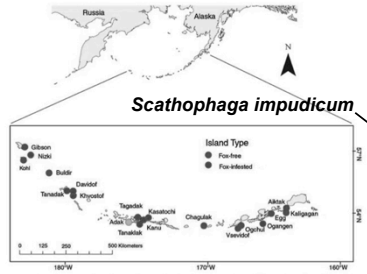


Fig. 1. The Aleutian archipelago with sample islands indicated in red (fox-infested) and blue (fox-free). Adak Island, the location of fertilization experiments, is indicated with a yellow dot.

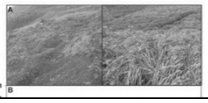
Fig. 2. Mean (±SE) values for parameters sampled on fox-infested (red) and fox-free (blue) islands in the Aleutian archipelago. (**A**) Photographs of typical plant communities on fox-infested (Ogangan Island) versus fox-free (Buldir Island) islands. (**B**) Logarithm of the density (birds m^{-2}) of breeding seabirds estimated from popula-

were based on contrasts among 18 islands (9 with foxes and 9 fox free) (Fig. 1) that were matched as carefully as possible for size and location in the archipelago (*12*).

A geographical information system (GIS) was used to superimpose spatially explicit grids over maps of each island. All islands were sampled at the completion of the growing season (August) between 2001 and 2003. We established a 30 m by 30 m plot at each of the grid crosspoints (12 to 32 per island, depending on island size) (*12*), within which we sampled plant species presence and cover; aboveground plant biomass; total soil N, P, and $\delta^{15}N$; and %N and $\delta^{15}N$ from a common grass (in most cases *Leymus mollis* but in some instances *Calamagrostis nutkaensis*) and forb (*Achillea borealis*) (*12*). At each island, we also haphazardly sampled $\delta^{15}N$ in at least five individuals from a diverse group of terrestrial consumers, including a mollusk (*Deroceras laeve*), arachnid (*Cybaeus reticulates*), dipteran (*Scathophaga impudicum*), and passerine bird (Lapland longspurs, *Calcarius lapponicus*, and song sparrows, *Melospiza melodia*). $\delta^{15}N$ was measured to determine the degree to which nitrogen-based nutrients were marine derived. Soils and organisms that obtain their N from locally fixed sources have lower $\delta^{15}N$ values than those that obtain their N from higher trophic levels, such as marine fish and zooplankton (*15*, *16*).

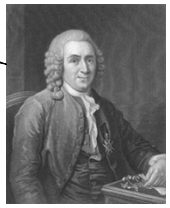
Breeding seabird densities were almost two orders of magnitude higher on fox-free than on fox-infested islands (Fig. 2B) (Mann-Whitney rank sum, $T = 36$, $P < 0.001$) (*12*). We estimate that this reduction in seabird abundance translates to a decline in annual guano input

Scathophaga impudicum



α (alpha) taxonomy

"*Nomina si nescis, periit cognito rerum*"



"If you don't know the names, the knowledge of things is lost"

C. Linnaeus

α (alpha) taxonomy

Tyrannosaurus rex
Biston betularia
Drosophila melanogaster

Easier to remember (& communicate?) with than:
9088-8980.6783
A793K2
or
Dm001.05

α (alpha) taxonomy

Taxonomists provide *identifications*

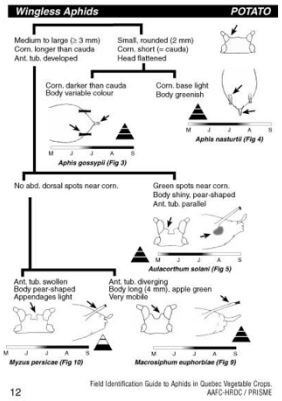
Identifications are:

Hypotheses that the unknown is conspecific with the *type* of the species

α (alpha) taxonomy

Taxonomists provide *identifications*

- Directly (if still alive & willing)
- Indirectly - publications (fraction of…)
  - Keys
  - Monographs
  - Field guides
  - Digital - websites, CDs



α (alpha) taxonomy

Taxonomists provide *identifications*

of species important for
- use
- control
- management

α (alpha) taxonomy

Identifications for:

All who "use" organisms
Many disciplines depend on identifications provided by taxonomy,
e.g.
ecologists
biostratigraphers
agriculturalists, (plants & pests)
public health officials, doctors
conservation biologists, etc.

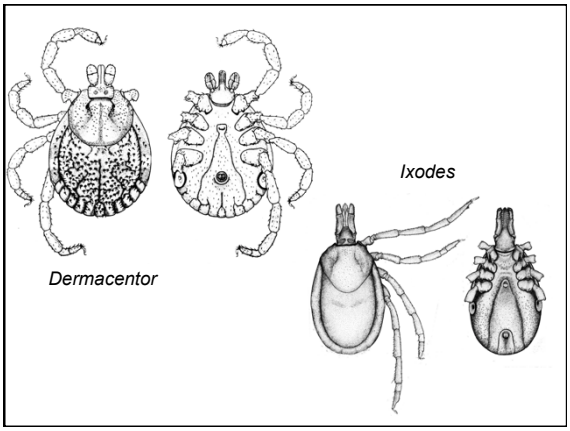
α (alpha) taxonomy

Identifications for:

Conservation Biology

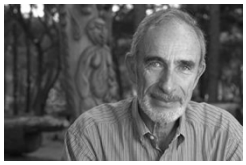
1. Identify "hot spots" of diversity

2. Identify species at greatest risk



Do we need taxonomic names?

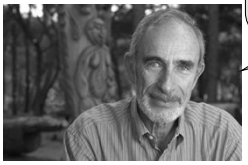
No…?



Paul Ehrlich

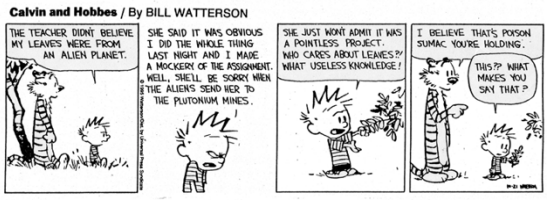
Do we need taxonomic names?

"[...] ecologists are often ill informed of both the value and the problems of systematics. That is true even though ecologists have long been parasitic on taxonomists."



Paul Ehrlich

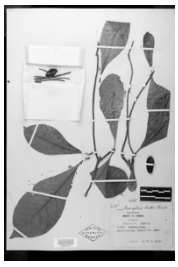
α (alpha) taxonomy



"useless knowledge?" - identification of species is rarely taught as part of a biology degree…

c.f. "use" of knowledge of astronomical bodies

α (alpha) taxonomy



Most identifications are done for free
Often not considered a valuable use of time for a scientist
Charge a fee similar to lawyer or doctor's fees ? ($100 - $500 / hour)

α (alpha) taxonomy

Importance of identifications so great …of such widespread value

But many people often forget or don't appreciate the work that was / is involved.. Or they think the work is finished

Or they think the "old way" is too difficult and want to replace it with new technology e.g. DNA barcoding

α (alpha) taxonomy

Systematists make & maintain *collections*

Have the training to collect, process, identify specimens

To curate and manage depositories of Earth's biodiversity

α (alpha) taxonomy

Value of collections (brief overview)

1. Critical role in identification
   - ecology, monitoring, pests, aliens, etc.
   - *majority* of described species have yet to be revised, keyed, etc.
   - MCZ type database, on-line

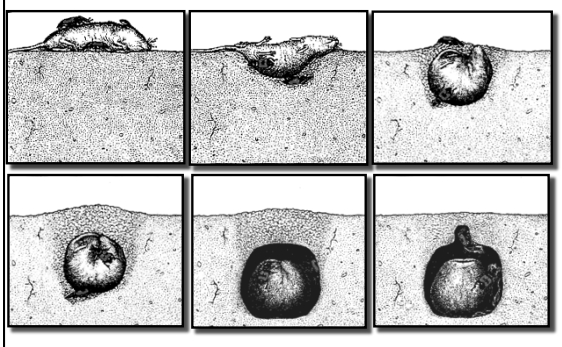
2. Voucher specimen deposition
   - allowing identifications to be checked

α (alpha) taxonomy

Value of collections (brief overview)

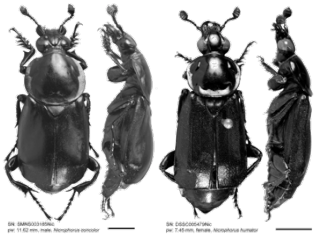
3. Revisionary taxonomy *requires* collections
   - impossible re-collect
   - myriad "new" species await discovery in collections

Small Carcass Monopolization



Character evolution:
Melanism

homology or homoplasy?



α (alpha) taxonomy

Value of collections (brief overview)

4. Specimens are data
   - locality data for GIS work
   - historic occurrences, conservation bio
   - as global climate changes…

α (alpha) taxonomy

Value of collections (brief overview)

5. Specimens have specimens
   - Symbionts, pollen & fungal spores

α (alpha) taxonomy

Value of collections (brief overview)

6. Archive of molecules - DNA data
   - Dry: some taxa more than others
   - Frozen collections

7. Teaching - biodiversity
   - university, public, etc.

α (alpha) taxonomy

"*Systematic biology has contracted at British universities to such an extent that it may be in danger of extinction as a sustainable discipline*."

- 1992 the Dainton Report on Systematics in the UK

α (alpha) taxonomy

Demographic trends in alpha taxonomy:

1990 survey

63% of taxonomists > 46 years old

Only 8% < 35 years old

α (alpha) taxonomy

"If the same demographic trends were found in a newly discovered lemur, specimens would be brought into a zoo and a captive breeding program initiated."

α (alpha) taxonomy

Systematics training in universities -

- molecular systematics
- phylogenetics
- rarely any training in alpha taxonomy
- NSF PEET grants

You should be able to

Describe biological systematics - its role, components, etc.

Distinguish alpha from beta taxonomy (phylogenetics)

Describe the value of alpha taxonomy - descriptions, identifications, collections, etc.