

# Developing a standardized list of entomological collection methods for use in databases

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## Abstract

The current natural history specimen databasing paradigm focuses on standardizing occurrence data: where and when a specimen was collected. In order to gather more information about a particular species, researchers also must know how to encounter, and possibly collect, the species. For entomological specimens, collection method terminology written on labels has not been standardized, and perhaps should not be; however, use of a broad-scale collection method framework may aid in communication among researchers especially within the context of public databases. Three main categories of collection methods are proposed: active human collecting; active specimen orientation; and passive specimen collection and/or concentration. General categories contain more specific sub-categories and so on. A bibliography of useful works describing entomological collection and curation methods (e.g., “How to make an insect collection”) is provided.

## Keywords

curation, entomology, insect, museum

## Introduction

For many invertebrates, distressingly little is known about their distribution, phenology, and natural history. Learning more about any aspect of a particular species requires three pieces of information: where to find it, when to go looking, and how to encounter it. For a select few species a meaningful encounter can take place without

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\* **Illustrator**

collecting the specimen, many dragonflies, bees, and butterflies can be sight identified, but for most species an accurate identification can be made only once a specimen is captured, after which it may be retained or released.

Recent technological advances and environmental regressions have precipitated a desire to create databases of natural history collections. To that end, Biodiversity Information Standards (TDWG) ([www.tdwg.org](http://www.tdwg.org)), was created to “establish international collaboration among biological database projects” (<https://www.tdwg.org/about/>). One result was creation of the Darwin Core standard (<http://rs.tdwg.org/dwc/>), a list of agreed upon terms used when reporting the occurrence of taxa, the when and where.

However, little standardization has been applied to collection method (see “dwc:sampling Protocol” <http://terms.tdwg.org/wiki/dwc:samplingProtocol>. Examples include: “UV light trap”, “mist net”, and “Penguins from space: faecal stains reveal the location of emperor penguin colonies”). As more material is added to databases and more databases are available online, standardization of the collection method field will become important, otherwise useful collection methods may become lost within a fog of overly vague or overly specific individualized terminology resulting in reduced searchability and loss of ability to collate records based on collection method. Additionally, a better understanding of collection method possibilities may help expand methods used when attempting to control or eradicate pests, study endangered species, conduct comprehensive surveys, or develop efficient surveys. While Darwin Core’s terminology concerning collection method may or may not change, the entomological, and wider natural history community, should consider adopting a more standardized list of collection method terms and/or concepts to use when databasing physical specimens.

The universe is complicated and diverse. Often, to ease communication or reduce overwhelming complexity, humans will create a small set of “boxes” or categories that, together, hold the majority of the entities within a particular system. For example, the life stages of an insect can be separated into four general “boxes”: egg, larva, pupa, and adult. Despite a wide variety of exceptions (ametabolous and hemimetabolous orders, subimagos, paedomorphic females, hypermetamorphosis, prepupae, etc.) these are useful and meaningful designations. It is important to remember that these categories are for human convenience, may or may not follow the natural world closely, and may be more (or less) useful in different forms to different users. Therefore, attempts to refine concepts to create one system that works equally well in all situations may be foolhardy (like the search for a single species-concept, or the definition of “life”).

A general outline of collection methods is presented below with examples (Whitman et al. 2019 independently started a very similar list). Referencing each method would become cumbersome, therefore a bibliography of some popular, useful, and/or interesting sources on collecting terrestrial and aquatic arthropods is provided. Several qualifications should be interjected here: 1) the list may not be complete and can/will be added to over time, the design allows for easy expansion; 2) equally valid alternative arrangements of the general concepts may exist; 3) the list as presented is biased for finer divisions among popular methods (lights: UV, MV, LED), and more generalized for less widely-used methods (thermal lure); 4) “sampling,” a *type* of collecting, is used to capture a subset of a population often for statistical analysis and not dealt with in

this scheme; 5) laboratory colonies are not listed below, presumably the progenitors were originally collected in one of the following manners.

## **Collection methods**

All insect collecting falls into three broad categories: 1) active human collecting; 2) active specimen orientation; and 3) passive collection and/or concentration (Fig. 1).

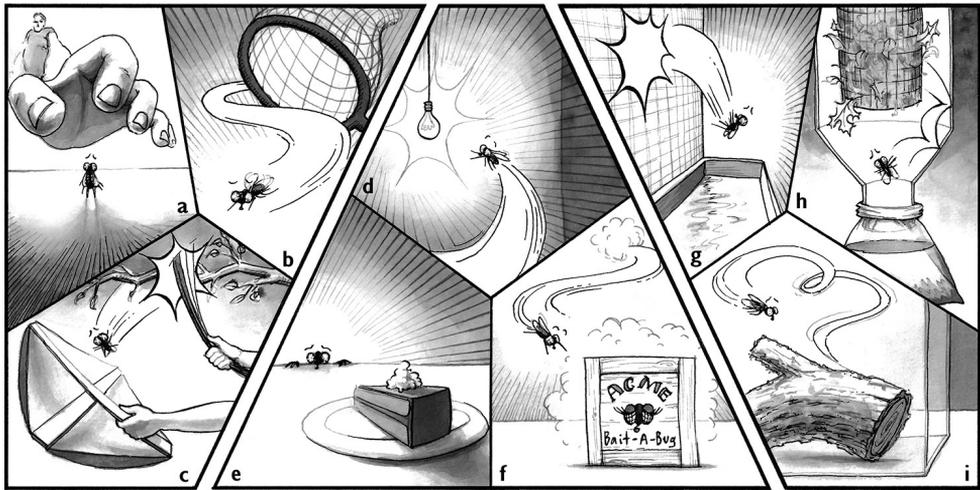
### **A. Active human collecting**

Active human collecting falls within three different categories: immediate collection of a specimen from the environment; filtration of the environment to concentrate specimens; and agitation of specimens from their present location. In each case the collector is present, specimens are removed from a location where they (more or less) would naturally occur, and the collector has some knowledge of when and where a specimen was collected.

1. Immediate collection of specimens with hands, aspirator, vial, etc. While a specialized tool may be used to collect the specimens (e.g., aspirator), here, specimens are recognized as such, individually targeted, and often directly removed from their native substrate by the collector (contrast with “sifting” below which lacks many of these elements). The method provides the highest accuracy and precision when reporting the location or activities of the specimen (host plant/animal, substrate, etc.).
  - 1.1 Hand/Direct.
2. Sequestration and concentration of specimens using a net/strainer/filter. A net, *sensu lato*, is a filtering device. The meaningful difference among nets is not design (aquatic, aerial) but the size of the holes, as that determines the smallest organism likely to be captured. Entomologists rarely consider mesh size except in aquatic situations. However, the interplay of substrate sampled (which carries ecological information) and net design creates the categories most often used to define net type.
  - 2.1 Net (general).
    - 2.1.1 Net – Aquatic (from water).
    - 2.1.2 Net – Aerial (collection of flying specimens).
    - 2.1.3 Net – Sweeping (collection of specimens that were attached to a substrate).
  - 2.2 Vacuum collector (hand held or backpack device that gathers and filters substrate, may be air or liquid based).
3. Separation of specimens from a substrate or matrix, collector induced (not sequestered or concentrated, see below).
  - 3.1 Agitation (direct or indirect stimulus used to induce movement that increases likelihood of capture: flooding, soil flotation, waving hand over the trunk of a tree, sifting litter into a pan and immediately collecting, etc.).
  - 3.2 Beating (mechanical removal from substrate).
  - 3.3 Fogging (chemical used to cause agitation on, or removal from, substrate).

## ACTIVE HUMAN COLLECTING

## PASSIVE SPECIMEN COLLECTION



## ACTIVE SPECIMEN ORIENTATION

**Figure 1.** Examples of the three general collecting technique categories. Active human collecting: **a** hand collecting **b** netting **c** using a beat sheet; active specimen orientation **d** light trapping **e** baiting **f** pheromone attractant; passive specimen collection **g** flight intercept trap **h** Winkler Sampler **i** emergence trap.

## B. Active specimen orientation

Specimens may be collected by altering the environment in such a way that the specimen actively moves toward the collection device or arena. Five general methods are employed: lights; chemicals; vibrations; heat; and ecological cues (often complex and utilize a combination of the preceding categories). Sections one through four below represent “attractants,” the factor that causes the specimen to reorient. They are often paired with a device from Category C when in use, for example a carrion baited (B.2.1) pitfall (C.1.1) trap. Often traps in section five are designed to combine an attractive feature and a passive collection method, for example a Lindgren funnel (B.5.2) incorporates an element of a flight intercept trap (C.1.2).

1. Positive phototaxis – specimen actively moves toward a light contrasted with darkness – night, caves, deep water. In general, this method is poorly known and little studied. The wavelengths of light differ among bulb type and are meaningful when attempting to recollect specimens and or understand specimen response to stimuli. Additional sub-categories could include specific wavelengths, wattages, etc. of each bulb type.
  - 1.1 Light (general, including standard visible-spectrum bulbs).
    - 1.1.1 Light – UV (general ultra-violet, typically fluorescent bulb).
    - 1.1.2 Light – MV (mercury vapor).
    - 1.1.3 Light – Metal halides.
    - 1.1.4 Light – LED (light emitting diode, presumably specific wavelengths/ ranges could be reported).

2. Chemical bait/lure – use of a medium that emits chemicals to attract specimens. A natural division of this category would be autochthonous (self-originating) and allochthonous (other-originating). Mimicry of chemicals with synthetics, etc. would fall within the category of the chemical being mimicked.
  - 2.1 Bait – animal matter (carrion, dung, CO<sub>2</sub>) (allochthonous).
  - 2.2 Bait – plant matter (sugar, ethanol) (allochthonous).
  - 2.3 Bait – Pheromones, etc. (autochthonous) synthetic or natural, e.g. collection of Cupedidae with bleach or male Strepsiptera by using a live female as bait.
3. Vibrational lure – use of vibrations to attract specimens.
  - 3.1 Sound – air or substrate born vibrations (used for mosquitoes, Asian citrus psyllid).
4. Thermal lure – use of differences in temperature to attract specimens.
  - 4.1 Heat – used to attract mosquitoes and ticks.
5. Ecological cues – structural alteration of the environment that passively mimics or creates potential habitat or resources that could be used by the specimen. Often multiple attributes, such as color, shape, and size are required to create an effective lure/trap. Two equally valid ways of subdividing ecological cue collection methods are: 1) design (color, structure, etc.); or 2) resource being mimicked (food source, habitat, etc.). Generally, collection with ecological cues will be specific to taxa and an enormous variety of sub-sub-sub (e.g., 5.1.1) categories potentially exist. Plants excel in utilization of this category for pollination and seed dispersal. Often inclusion of chemicals, sounds, heat, etc. may render the trap more effective.
  - 5.1 Food resource trap – specimens orient toward the trap because it appears to represent a possible food source (yellow pan traps, trap crop, etc.).
  - 5.2 Habitat resource trap – specimens orient toward the trap because it appears to represent appropriate habitat (Lindgren funnel, bee “hotel”, purple panel trap, etc.).

**Alternative 5.1:**

Color trap – specimens actively orient towards the trap because of its color (yellow pan trap, purple panel trap, etc.).

**Alternative 5.2:**

Structure trap – creation of a seemingly suitable habitat (carpenter bee trap, Lindgren funnel, bee “hotel”, trap crop, etc.).

### **C. Passive specimen collection and/or concentration**

A structure is introduced into the environment, or an arena is created, where specimens, by virtue of their general movement, concentrate themselves in space and/or time.

1. Passive Trap – alteration of the environment in such a way that specimens unwittingly place themselves in a situation from which they cannot escape.
  - 1.1 Pitfall, ramp trap – gravity is used to collect and keep specimens in a location, essentially a “walking intercept trap”. The trap may be augmented with a barrier.

- 1.2 Flight Intercept Trap (FIT), window trap – the path of flying insects is obstructed by a barrier. Specimen reaction to the barrier is often taxon specific, therefore placement of the collection device is meaningful. Height of the trap (ground based, canopy, etc.) may also be important.
  - 1.2.1 Malaise trap – specimens collected at top.
  - 1.2.2 Ground based FIT – specimens collected at bottom.
  - 1.2.3 Canopy Trap – elevated, often collection at top and bottom (Sante Trap).
- 1.3 Flow intercept trap – insects in flowing water are obstructed by a barrier and waylaid or cannot escape.
- 1.4 Suction trap – air flow is used to collect and keep specimens in a location.
- 1.5 Glue – “sticky” material used to hold specimens in place (Tanglefoot® placed on a log or standing dead tree).
2. “Sifting” – Short term concentration and manipulation of inhabited material in such a way as to induce specimens to migrate to a collection point. The method is generally defined by the way the material is manipulated.
  - 2.1 Berlese/Tullgren funnel – habitat manipulation through heat (Berlese) or heat and light (Tullgren).
  - 2.2 Winkler sampler – habitat manipulation through increased surface area and drying.
3. Emergence – long term sequestration of inhabited material with the aim of allowing immature specimens to mature before collection. (As opposed to rearing. Rearing a specimen requires that you have already collected it, then provide it with resources and time to continue its life cycle.) Often the arena is designed so that emergent specimens concentrate themselves in a pitfall- or Malaise-type apparatus.
  - 3.1 Emergence chamber – material removed from original site, often fully enclosed.
  - 3.2 Emergence trap – full or partial enclosure of material in the field.

## Discussion

The above scheme allows for standardization of collection methods within and among databases. The ability to designate a collection method using general standard sets rather than specific, often regional, terms will aid in present and future communication. For example: “treading” and “flooding” are both A.3.1; “Brown sampler” and “vacuum benthos sampler” are both A.2.2; and “freshet,” “rejectamenta,” and “flood rubbish” are different terms for C.1.3 that occurs during a flood. For some methods separation of attractant used and method of capture will be important.

Additionally, researchers can build a better picture of which general collection methods are best at collecting specific taxa, the highest biodiversity, or even members within a particular guild. However, verbal descriptions can and should be maintained. For example, descriptions such as, “sifting pine duff,” “oak leaf litter” “Berlese Hemlock,” and “Berl. oak stump” all fall within the same collecting method, C.2, but all contain additional ecological information as well.

The creation and implementation of any standardized collection methods will require an extended discussion by the entomological and biodiversity databasing communities. The above list is provided to begin that discussion. Once approved, those standard methods can be provided as a drop-down list within databases. The numbering scheme can be retained to maintain organization and to illustrate relatedness of techniques, and verbal descriptions should be available to offer guidance.

The following is one possible implementation schema. Collection methods recorded on labels and within notes-sections of databases will continue to be as individualized, general, or specific as collectors wish, similar to the verbal locality on labels (e.g. 24 km SE Cole Camp). Within the database itself, a specific field would accept numbered methods. A drop-down list and descriptions can be provided. Multiple collection methods can be selected, similar to key-words for a manuscript. For example, specimens collected using an emergence chamber would get “C.3.1”; a CDC trap that emits CO<sub>2</sub> and uses a UV light would be “B.1.1.1, B.2.1”. If the databasing community is so inclined, additional fields related to collection method can be added, such as killing agent, preservative, minimum and maximum time between specimen death and retrieval, etc.

While compiling the list above it became apparent that no single source contained descriptions of all collection methods known, even those which attempted to be as comprehensive as possible (e.g., Schauff 2001). Therefore, a bibliography is provided containing popular, useful, and/or interesting English language sources on collecting and preserving terrestrial and aquatic arthropods (see Bibliography and References, Suppl. material 1). Many of these works have gone through multiple editions, even though a single edition is cited. Some methods of collection and preservation have fallen out of favor or have been lost to the ages but are just as useful today as in the past, thus perusal of older literature is highly recommended.

However, two general areas need to be updated: chemical usage; and pinned insect labeling. The combination of the two sections below to the materials in the bibliography will go a long way toward elevating those references to a modern standard.

**Chemicals:** Many chemicals recommended in the past to kill or preserve specimens are now known to be deadly dangerous to humans, and more importantly, can damage the specimen DNA. Authors of new material, especially targeted at younger collectors, have removed dangerous chemicals from their works (modern 4-H manuals (Hall 1998) no longer recommend cyanide (Jones 1940)) and modern workers are more consciousness of killing and preservation methods. When utilizing, citing, or recommending older works, care should be taken to point out some chemical recommendations should not be followed. Consult Whitman et al. (2019) for a discussion on modern views of chemicals used for killing and preserving insects.

**Labeling:** Recent sources continue to repeat labeling recommendations that were created in a pre-personal printing era (e.g., Gibb and Oseto 2012). Those “systems” spread information across multiple labels (1: locality and date, 2: collector, 3: disposition of specimen) while today, all that information can be contained on a single label. Wheeler et al. (2001) provide a good description of label content and format (but not spacing). Modern specimen labeling should emphasize: 1) making sure that labels are positioned

correctly laterally to reduce the specimen footprint and vertically to leave space for additional labels below; 2) keeping labels small and rectangular; and 3) making sure the label does not get bent or the hole enlarged. Correct labeling takes no more time than incorrect labeling and saves curators and workers an immense amount of work and frustration.

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## References

The works cited below consist of, or contain, a section on insect collection and curation methods. A few additional sources specific to particular methods that also provide literature reviews are included.

- Arnett Jr RH (2000) *American Insects: A Handbook of the Insects of America North of Mexico* (2<sup>nd</sup> edn). CRC Press, NY, 1003 pp. <https://doi.org/10.1201/9781482273892>
- Arnett Jr RH, Jacques Jr RL (1985) *Insect Life: A Field Entomology Manual for the Amateur Naturalist*. Prentice-Hall, Englewood Cliffs, NJ, 354 pp.
- Banks N (1909) Direction for collecting and preserving insects. *United States National Museum Bulletin* 67: 1–135. <https://doi.org/10.5479/si.03629236.67.i>
- Beirne BP (1955) *Collecting, Preparing and Preserving Insects*. Canada Department of Agriculture. Science Service, Entomology Division, Publication 932, 133 pp.
- Bioquip Products, Inc (2003) *How to make an insect collection* 3<sup>rd</sup> ed. Rancho Dominguez, CA, 32 pp.
- Borror DJ, White RE (1970) *A Field Guide to the Insects of America North of Mexico*. Peterson Field Guide Series. Houghton Mifflin, Boston, 404 pp.
- Catanach TA (2012) Invertebrate sampling methods for use in wildlife studies. In: Silvy NJ (Ed.) *The Wildlife Techniques Manual Research Volume 1* (7<sup>th</sup> edn). The Johns Hopkins University Press, Baltimore, MD, 336–348.
- Chu HF (1949) *How to Know the Immature Insects*. Pictured Key Nature Series. Wm. C. Brown Company, Dubuque, IA, 234 pp.
- Comstock AB (1923) Directions for collecting and preserving insects. *Cornell Extension Bulletin* 59: 1–12.
- Comstock AB (1947) *Handbook of Nature-Study*. Comstock Publishing Company, Ithaca, NY, 937 pp.
- Comstock JH (1914) *Insect Life. An Introduction to Nature-Study and a Guide for Teachers, Students, and Others Interested in the Out-of-Door Life*. D Appleton and Co., NY, 349 pp.
- Dindal DL (1990) *Soil Biology Guide*. John Wiley and Sons, NY, 1349 pp.

- Eymann J, Degreef J, Häuser Ch, Monje JC, Samyn Y, VandenSpiegel D (2010) Manual on Field Recording Techniques and Protocols for All Taxa Biodiversity Inventories and Monitoring 8(1–2): 1–653.
- Ferro ML, Carlton CE (2011) A practical emergence chamber for collecting Coleoptera from rotting wood, with a review of emergence chamber designs to collect saproxylic insects. *The Coleopterists Bulletin* 65: 115–124. <https://doi.org/10.1649/072.065.0202>
- Fox RC (1968) *Collecting, Fixing, Preserving, and Shipping of Soft-Bodied Arthropods*. South Carolina Agricultural Experiment Station, Miscellaneous Station Circular, Clemson University, Clemson, SC, 7 pp.
- Gibb TJ, Oseto CY (2012) *How to Make an Awesome Insect Collection! A Beginners Guide to Finding, Collecting, Mounting, Identifying and Displaying Insects*. 2<sup>nd</sup> edition. Perdue Extension, ID-401, Perdue University, 216 pp.
- Hall M (1998) 4-H Project Book. *Entomology: Insect Study (7<sup>th</sup>–9<sup>th</sup> Grade Level)*. Louisiana Cooperative Extension Service Publication 2609, 47 pp.
- Hienton TE (1974) Summary of investigations of electric insect traps. United States Department of Agriculture Technical Bulletin 1498: 1–136.
- Hopkins JD, Studebaker G, Lorenz GM III, Loftin KM, Akin S (2007) Making an insect collection. University of Arkansas Division of Agriculture [MP83-PD-3-13RWC]: 1–35.
- Howard LO (1923) *The Insect Book: A Popular Account of the Bees, Wasps, Ants, Grasshoppers, Flies and other North American Insects Exclusive of the Butterflies, Moths and Beetles, with Full Life Histories, Tables and Bibliographies*. Doubleday, Page & Company, Garden City, NY, 429 pp.
- Jaques HE (1947) *How to Know the Insects*. Pictured Key Nature Series. Wm. C. Brown Company, Dubuque, IA, 205 pp.
- Jones MP (1940) 4-H club insect manual. United States Department of Agriculture Miscellaneous publication No. 318: 1–63. <https://doi.org/10.5962/bhl.title.65490>
- Kaston BJ (1972) *How to Know the Spiders*. 2<sup>nd</sup> edition. W.M. C. Brown Company Publishers, Dubuque, IA, 289 pp.
- Klots AB (1932) *Directions for Collecting and Preserving Insects*. Ward's Natural Science Establishment. Rochester, NY, 29 pp.
- Knudsen JW (1966) *Biological Techniques. Collecting, Preserving, and Illustrating Plants and Animals*. Harper and Row, NY, 525 pp. <https://doi.org/10.1086/405509>
- Lutz FE (1917) How to collect and preserve insects. *American Museum of Natural History Guide Leaflet Series* 39: 1–22.
- Lutz FE (1948) *Field Book of Insects of the United States and Canada, Aiming to Answer Common Questions*. 3<sup>rd</sup> edition. G. P. Putnam's Sons, NY, 510 pp.
- Mansuy MC (1929) *Collection and Preservation of Insects for Use in the Study of Agriculture*. U.S. Department of Agriculture Farmer's Bulletin No. 1601, 20 pp.
- Marshall SA (2006) *Insects their Natural History and Diversity. With a Photographic Guide to Insects of Eastern North America*. Firefly Books, Buffalo, NY, 718 pp.
- Martin JEH (1977) *The Insects and Arachnids of Canada Part 1. Collecting, Preparing, and Preserving Insects, Mites, and Spiders*. Publication no. 1643, Canada Department of Agriculture, Québec, 182 pp.

- McDunnough MC (1919) Directions for collecting and preserving insects. Dominion of Canada Department of Agriculture Entomological Branch Circular 12: 1–14. <https://doi.org/10.5962/bhl.title.65610>
- Merritt RM, Cummins KW, Resh VH, Batzer DP (2008) Chapter 3. Sampling aquatic insects: collection devices, statistical considerations, and rearing procedures. In: Merritt RW, Cummins KW, Berg MB (Eds) *An Introduction to the Aquatic Insects of North America*, 4<sup>th</sup> ed. Kendall/Hunt, Dubuque, IA, 15–37.
- Millar IM, Uys VM, Urban RP (2000) *Collecting and Preserving Insects and Arachnids. A Manual for Entomology and Arachnology*. Ultra Litho (Pty) Ltd., Johannesburg, South Africa, 105 pp.
- Miller D (2014) *Adventures with Insects*. 4-H Entomology Project Book. Virginia Cooperative Extension. Publication 444–408, 20 pp.
- Nageleisen LM, Bouget C (2009) Forest insect studies: methods and techniques. Key considerations for standardization. An overview of the reflections of the “Environmental Forest Inventories” working group (Inv. Ent. For.). *Office National des Forêts, Les Dossiers Forestiers* 19: 1–144. [https://doi.org/10.1007/978-90-481-3233-1\\_2](https://doi.org/10.1007/978-90-481-3233-1_2)
- Needham JG (1943) *Introducing Insects: A Book for Beginners*. The Jaques Cattell Press, Lancaster, PA, 129 pp.
- Oldroyd H (1958) *Collecting, Preserving and Studying Insects*. Hutchinson Scientific and Technical, London, 327 pp.
- Oman PW, Cushman AD (1960) *Collection and preservation of insects*. U. S. Department of Agriculture Miscellaneous Publication No. 601: 1–42.
- Oman PW (1952) How to collect and preserve insects for study. In: Stefferud A (Ed.) *Insects: The Yearbook of Agriculture 1952*. United States Department of Agriculture, U.S. Government Printing Office, 65–78.
- Owens BE, Carlton CE (2015) “Berlese vs. Winkler”: comparison of two forest litter Coleoptera litter extraction methods and the ECOLI (extraction of Coleoptera in litter) protocol. *The Coleopterists Bulletin* 69(4): 645–661. <https://doi.org/10.1649/0010-065X-69.4.645>
- Packard Jr AS (1873) Directions for collecting and preserving insects. *Smithsonian Miscellaneous Collections* 261: 1–55.
- Packard AS (1890) *Entomology for Beginners. For the Use of Young Folks, Fruit-Growers, Farmers, and Gardeners*. Henry Holt and Company, NY, 367 pp.
- Peterson A (1937) *A Manual of Entomological Equipment and Methods*. Part I. Edwards Brothers, Inc., Ann Arbor, MI, 185 pp. [not consecutively paginated]
- Peterson A (1937) *A Manual of Entomological Equipment and Methods*. Part II. Edwards Brothers, Inc., Ann Arbor, MI, 334 pp.
- Post RL, Aarhus DG, Perkins HF, Thomasson GL (1969) *Insect Collecting Manual*. Department of Entomology Agricultural Experiment Station North Dakota State University. *North Dakota Insects* 8: 1–36.
- Riley CV (1892) Directions for collecting and preserving insects. *Bulletin of the United States National Museum* 39 (Part F): 1–147. <https://doi.org/10.5962/bhl.title.2506>
- Ross HH (1934) *How to Collect and Preserve Insects*. Illinois State Natural History Survey Circular 25: 1–27. <https://doi.org/10.5962/bhl.title.46167>

- Ross HH (1941) How to Collect and Preserve Insects. Natural History Survey Division Circular 39: 1–48.
- Samouelle G (1826) General Directions for Collecting and Preserving Exotic Insects and Crustacea: Designed for the use of Residents in Foreign Countries, Travelers, and Gentlemen going Abroad. With Illustrative Plates. Longman, Rees, Orme, Brown, and Green, London, 72 pp. <https://doi.org/10.5962/bhl.title.31086>
- Sanders DP, Lehker GE, Matthew DL (1980) How to Collect, Preserve and Identify Insects. Extension Circular 509. Cooperative Extension Service, Purdue University, Lafayette, IN, 51 pp.
- Sanderson DW, Jackson CF (1912) Elementary Entomology. Ginn and Co., NY, 372 pp. <https://doi.org/10.5962/bhl.title.29213>
- Schauff ME (2001) Collecting and preserving insects and mites: techniques and tools. [Updated and modified WWW version of Steyskal GC, Murphy WL, Hoover EH (Eds) (1986) Insects and mites: techniques for collection and preservation.] Agricultural Research Service, USDA, Miscellaneous Publication 1443: 1–103. [http://www.ars.usda.gov/SP2UserFiles/ad\\_hoc/12754100CollectingandPreservingInsectsandMites/collpres.pdf](http://www.ars.usda.gov/SP2UserFiles/ad_hoc/12754100CollectingandPreservingInsectsandMites/collpres.pdf)
- Skvarla MJ, Larson JL, Dowling APG (2014) Pitfalls and preservatives: a review. *Journal of the Entomological Society of Ontario* 145: 15–43.
- Smithers C (1981) Handbook of Insect Collecting: Collection, Preparation, Preservation and Storage. David and Charles, London, 120 pp.
- Southwood TRE (1975) Ecological Methods. With Particular Reference to the Study of Insect Populations. Chapman and Hall, London, 391 pp.
- Southwood TRE, Henderson PA (2000) Ecological Methods. Third Edition. Blackwell Science, London, 575 pp.
- Stoltz RL, Homan HW, Craig MJ (2002) Preparing insect specimens for exhibit: for 4-H entomology projects. University of Idaho Extension #82358: 1–9.
- Swain RB (1948) The Insect Guide: Orders and Major Families of North American Insects. Doubleday Nature Guide Series. Doubleday and Company, Garden City, NY, 261 pp.
- Triplehorn CA, Johnson NA (2005) Borror and DeLong's Introduction to the Study of Insects. 7<sup>th</sup> ed. Brooks/Cole, Belmont, CA, 864 pp.
- Ubick D, Paquin P, Cushing PE, Roth V (2005) Spiders of North America: An Identification Manual. American Arachnological Society, Keen, NH, 377 pp.
- Upreti DR, Kapoor VC (1979) Collection, Preservation and Identification of Insects. Tribhuvan University Press, Kathmandu, Nepal, 94 pp.
- Upton MS (1991) Methods for collecting, preserving, and studying insects and allied forms. Fourth edition. The Australian Entomological Society, Miscellaneous Publication 3: 1–86.
- Urquhart FA (1949) Introducing the Insect. Henry Holt and Company, NY, 287 pp.
- Wards (1945) How to Make an Insect Collection. Ward's Natural Science Establishment, Inc. Rochester, NY, 32 pp.
- Wards (1958) How to Make an Insect Collection: A Beginner's Guide to the Methods and Materials of Insect Collecting, Revised and Expanded. Ward's Natural Science Establishment, Inc. Rochester, NY, 68 pp.

- Wards (1967) How to Make an Insect Collection. A Beginner's Guide to the Methods and Materials of Insect Collecting, Revised and Expanded. Ward's Natural Science Establishment, Inc. Rochester, NY, 66 pp.
- Wheeler TA, Huber JT, Currie DC (2001) Label data standards for terrestrial arthropods. Biological Survey of Canada (Terrestrial Arthropods), Document Series No. 8: 1–19.
- Whitman JD, Yanega D, Watson CBG, Strode VW (2019) Chapter 17: Collection and preservation of terrestrial arthropods. In: Yong WH (Ed.) Biobanking: Methods and Protocols. Methods in Molecular Biology, Vol. 1897. Humana Press, NY, 163–189. [https://doi.org/10.1007/978-1-4939-8935-5\\_17](https://doi.org/10.1007/978-1-4939-8935-5_17)
- Wilcox EM (1901) Directions for collecting and preserving insects and plants. Oklahoma Agricultural Experiment Station Circular of Information 3: 1–15.
- Williamson EB (1916) Directions for collecting and preserving specimens of dragonflies for museum purposes. University of Michigan Museum of Zoology Miscellaneous Publications 1: 1–15.

## **Supplementary material I**

### **Bibliography**

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