Inventory Methods for Terrestrial Arthropods

Standards for Components of British Columbia's Biodiversity No. 40

Prepared by
Ministry of Environment, Lands and Parks
Resources Inventory Branch
for the Terrestrial Ecosystems Task Force
Resources Inventory Committee

October 19, 1998

Version 2.0

Published by the
Resources Inventory Committee

Canadian Cataloguing in Publication Data

Main entry under title:

Inventory methods for terrestrial arthropods [computer file]

(Standards for components of British Columbia's biodiversity ; no. 40)

Previously issued as: Standardized inventory methodologies for components of British Columbia's biodiversity. Terrestrial arthropods, 1997.

Available through the Internet.

Issued also in printed format on demand.

Includes bibliographical references: p.

ISBN 0-7726-3563-3

1. Arthropods - British Columbia - Inventories - Handbooks, manuals, etc. 2. Ecological surveys - British Columbia - Handbooks, manuals, etc. I. BC Environment. Resources Inventory Branch. II. Resources Inventory Committee (Canada). Terrestrial Ecosystems Task Force. III. Title: Standardized inventory methodologies for components of British Columbia's biodiversity. Terrestrial arthropods. IV. Series.

QL434.52.C3I58 1998 333.95'5 C98-960137-4

Additional Copies of this publication can be purchased from:

Superior Repro
#200 - 1112 West Pender Street
Vancouver, BC V6E 2S1
Tel: (604) 683-2181
Fax: (604) 683-2189

Digital Copies are available on the Internet at:
http://www.for.gov.bc.ca/ric

Preface

This manual presents standard methods for inventory of Terrestrial Arthropods in British Columbia at three levels of inventory intensity: presence/not detected (possible), relative abundance, and absolute abundance. The manual was compiled by the Elements Working Group of the Terrestrial Ecosystems Task Force, under the auspices of the Resources Inventory Committee (RIC). The objectives of the working group are to develop inventory methods that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species component of biodiversity.

This manual is one of the Standards for Components of British Columbia's Biodiversity (CBCB) series which present standard protocols designed specifically for group of species with similar inventory requirements. The series includes an introductory manual (Species Inventory Fundamentals No. 1) which describes the history and objectives of RIC, and outlines the general process of conducting a wildlife inventory according to RIC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. The Species Inventory Fundamentals manual provides important background information and should be thoroughly reviewed before commencing with a RIC wildlife inventory. RIC standards are also available for vertebrate taxonomy (No. 2), animal capture and handling (No. 3), and radio-telemetry (No. 5). Field personnel should be thoroughly familiar with these standards before engaging in inventories which involve any of these activities.

Standard data forms are required for all RIC wildlife inventory. Survey-specific data forms accompany most manuals while general wildlife inventory forms are available in the Species Inventory Fundamentals No. 1 [Forms] (previously referred to as the Dataform Appendix). This is important to ensure compatibility with provincial data systems, as all information must eventually be included in the Species Inventory Datasystem (SPI). For more information about SPI and data forms, visit the Species Inventory Homepage at:
http://www.env.gov.bc.ca/wld/spi/ric_manuals/

It is recognized that development of standard methods is necessarily an ongoing process. The CBCB manuals are expected to evolve and improve very quickly over their initial years of use. Field testing is a vital component of this process and feedback is essential. Comments and suggestions can be forwarded to the Elements Working Group by contacting:

Species Inventory Unit
Wildlife Inventory Section, Resource Inventory Branch
Ministry of Environment, Lands & Parks
P.O. Box 9344, Station Prov Govt
Victoria, BC V8W 9M1
Tel: (250) 387 9765

Acknowledgments

Funding of the Resources Inventory Committee work, including the preparation of this document, is provided by the Corporate Resource Inventory Initiative (CRII) and by Forest Renewal BC (FRBC). Preliminary work of the Resources Inventory Committee was funded by the Canada-British Columbia Partnership Agreement of Forest Resource Development FRDA II.

The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First Nations peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report “The Future of our Forests”.

For further information about the Resources Inventory Committee and its various Task Forces, please contact:

The Executive Secretariat

Resources Inventory Committee

840 Cormorant Street

Victoria, BC V8W 1R1

Tel: (250) 920-0661

Fax: (250) 384-1841

http://www.for.gov.bc.ca/ric

Terrestrial Ecosystems Task Force

All decisions regarding protocols and standards are the responsibility of the Resources Inventory Committee. Background information and protocols presented in this document are based on Version 1.1 of this manual and the unpublished government report, *Methodology for Sampling Terrestrial Arthropods in British Columbia*, prepared by Neville Winchester and G.G.E. Scudder with editorial assistance from Tom Ethier and Ruth van den Driessche. The current version of this manual includes a more rigorous data analysis and survey design section contributed by Dr. Qiwei Liang (Maple Leaf Science Services), with helpful review comments from John Boulanger (Integrated Ecological Research) and Dr. Charles Krebs (UBC).

The Standards for Components of British Columbia’s Biodiversity series is currently edited by James Quayle with data form development by Leah Westereng.

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

Biodiversity is a concept that has only recently attracted significant attention from ecologists and other researchers (Hamilton 1991). Biodiversity can be defined as the integration of biological variability across all scales, from the genetic, through species, to ecosystems and landscapes (Walker 1992). Threats to biodiversity are global, and are usually a direct result of human impact that contributes to reduction of genetic diversity through habitat loss and fragmentation (see Soulé 1991). May (1992) notes that the ultimate goal in recording biological diversity is to build a factual foundation for answering basic questions about evolution and ecology. However, the diversity of organisms and ecological concepts has created the potential to bury ecologists in a profusion of special cases (Hoekstra *et al*. 1991). Nowhere is this more apparent than in the entomological community. Species estimates once ranged from 1.5 to 1.8 million; recent projections range from 5 to 6 million (see Hammond 1990) to as many as 30 million (see Erwin 1983). Clearly we have to expand the catalogue of life, and implement conservation measures that will give us time to do basic research.

In British Columbia, we are entering a crisis situation in several of our natural ecosystems, including the coastal old-growth forests and the Southeast Okanagan grasslands. We cannot be expected to make reasonable decisions designed to maintain biodiversity when we have yet to establish a co-ordinated program to complete the initial step of gathering inventory information. Strict sampling protocols that define proper data collection techniques must be developed, to ensure that comparisons are broadly applicable. The most significant components of ecosystem processes must be identified if we are to direct our best conservation efforts towards minimizing impacts on biodiversity in British Columbia. As Platnick (1991) states, "Speaking about biodiversity is essentially equivalent to speaking about arthropods. In terms of species, other animal and plant groups are just a gloss on the arthropod theme." This view was supported by the International Union for the Conservation of Nature (IUCN) in 1991, when it passed a resolution on the conservation of insects and other invertebrates. The Entomological Society of Canada also passed a resolution concerning the study of biodiversity of terrestrial arthropods in 1991 (Entomological Society of Canada 1992). Arthropods are an integral part of all ecosystems, and are important components of natural diversity that need to be identified (see May 1986).

The estimated number of terrestrial arthropods in British Columbia ranges from 40,000 to 50,000 (Cannings 1992). There needs to be a concerted sampling effort to catalogue even this conservative estimate. An arthropod survey involves the collecting and recording of ecological groups, in a series of stations throughout a defined area. The Biological Survey of Canada has approved the principle that meaningful inventories require detailed knowledge at the species level**.** This suggests that any sampling program must implement a protocol that provides detailed information on community structure and function in selected key regions and habitats. The protocol should ensure: (1) Identification of arthropod groups that characterize the diversity associated with key habitats, at the macro- and microscale levels. (2) Avoidance of single-species approaches, and initial concentration on arthropod groups that trained systematists can identify (e.g., Arachnida, Coleoptera, Hemiptera). The absence of an adequate systematic framework makes this step of crucial importance. *(3) All* representative subhabitats in a given system should be sampled using a quantitative approach. Quantitative sampling requires a well-defined objective that includes the most appropriate collection technique for the habitat of choice.

This inventory manual provides standardized protocol for the inventory of Terrestrial Arthropods. It includes a synopsis of appropriate inventory methods (from collections through identifications) and survey design.

2. INVENTORY GROUP

Table 1. Taxa captured by various sampling techniques

TAXA	Pan/Pitfall	Window/Malaise	Berlese	Beating	Sweeping	Searching	Sifting	Netting & Chasing	Dipnet - sweeping	Dipnet - shuffling	Light trap
MOLLUSCA (fresh water)						X			X	X	
ANNELIDA (terrestrial)	X		X								
CRUSTACEA AMPHIPOD						X			X	X	
ISOPODA						X			X	X	
ARACHNIDA SOLPUGIDA	X										
SCORPIONIDA	X					X					
ARANEAE	X		X	X	X	X	X		X		
ACARIFORMES			X						X	X	
DIPLODA	X		X			X	X				
DIPLURA			X								
COLLEMBOLA	X		X								
INSECTA MICROCORYPHIA	X		X			X					
ODONATA								X	X	X	
EPHEMEROPTERA				X	X	X		X	X	X	X
PLECOPTERA	X			X	X	X		X	X	X	
NOTOPTERA						X					
DICTUOPTERA	X					X					
GRYLLOPTERA	X			X	X	X		X			X
ORTHOPTERA	X	X		X	X	X		X			X
HETEROPTERA	X	X	X	X	X	X	X	X	X		X
HOMOPTERA (Auchenoprrhyncha)	X	X		X	X	X		X			X
MEGALOPTERA		X		X	X	X		X	X	X	X
RAPHIDIOPTERA		X		X	X	X		X			X
NEUROPTERA		X		X	X	X		X			X
COLEOPTERA (Carabidae, etc.)	X	X	X	X	X	X	X	X	X		X
MECOPTERA		X				X		X			
DIPTERA (some)	X	X		X	X	X		X			
LEPIDOPTERA (Macrolepidoptera)								X			X
TRICHOPTERA		X		X	X	X			X	X	X
HYMENOPTERA (Aceuleates)	X	X	X	X	X	X		X			

3. Protocols

3.1 Office Procedures

3.1.1 Selection of Sampling Site(s)

- Refer to recommendations of Scudder (1993).

3.1.2 Crew Hiring

- A minimum of three crew members must be properly trained in the entomological techniques to be used.
- A trained entomologist should be in charge of the training and running of the sampling program. Experience should include familiarization with sample design, statistics, specimen preparation, and experience with field sampling in diverse habitats.
- At least one crew member should have a valid CPR ticket and First Aid ticket.

3.1.3 Determination of Field Procedures

- Sampling chronology is dependent on area (see Scudder 1993).
- Selection of procedures should follow those outlined in this report.
- Sampling effort, time and costs should follow the recommendations proposed by Scudder (1993).

3.2 Specimen Preparation and Identification

Due to the large number of specimens that this program will generate it is imperative that trained parataxonomists be used to separate all samples to Order, and in most cases to Family.

Specimen preparation is crucial. The techniques used for proper specimen preparation depend on:

1. taxon,
2. medium used to preserve specimens, and
3. taxonomic expertise enlisted to do the identifications.

This protocol should be established before the inventory is initiated. It is therefore essential to plan a co-ordinated effort to deal with specimens.

For example, the old-growth biodiversity study from the Carmanah Valley has enlisted the help of 52 taxonomists/systematists from across North America and Europe. Specimen preparation is largely dependent on who will do the identifications. It is recommended that a list of taxonomic help with specifications for sample preparation be established before the inventory is initiated. The Carmanah arthropod biodiversity project (Winchester 1992) could be used as a model. Long-term care of samples and collections should follow the recommendations of Scudder (1993).

3.3 Survey Sampling Design

To achieve maximum efficiency, a survey should be fully designed before any fieldwork is initiated. Previous fauna inventories have generally been the purview of two scientific disciplines: systematics and ecology. Systematic work tends to be highly proficient in maximizing species richness and relating data in the form of sample area catch per unit effort. Usually the end result of this "museum collecting" (see Coddington *et al*. 1991) is a list of species encountered. Conversely, under the umbrella of ecological-oriented sampling, species abundance, spatial distribution and biodiversity are usually the concerns. However, ecological approaches are generally not as proficient in obtaining maximum species richness measures. Ideally, the desired survey design should be a combination of both techniques. In this manner, inventory information can be maximized and quantified to answer basic questions about biodiversity. It is important to note that simple species lists do not provide enough information to answer biodiversity questions.

Terrestrial arthropods represent a very large group of organisms. They vary considerably in biology and habitats. The small body size of many species makes direct sampling difficult and often, sampling devices such as traps have to be used. As many factors can affect the placement of traps and catches, sampling design and population estimation for arthropods remains a challenging subject. Although some sophisticated sampling methods have been developed for estimating relative species abundance, mainly insects, sampling theory for terrestrial arthropods is largely in its infancy. A detail discussion of sampling design for arthropods is beyond the scope of this manual. However, some general principles can be summarized as follows:

1. State clearly the objectives of the survey sampling. This is a good time to also review the type of analyses which may be required (see Statistical Data Analysis) so that you are familiar with what information will be required to meet your objectives. Reasonable objectives for inventory of arthropods include:
    - To investigate species richness, diversity, proportion, or dominance in a specified area or habitat.
    - To investigate the relative abundance of a major species among habitats or over time. This can be accomplished by calculating mean individuals collected at sample units, or through binomial sampling (see Statistical Data Analysis - Binomial Sampling).

2. Define the sampling universe, which is the habitats occupied by the target organisms. In forests, any stand characterized by homogeneous forest conditions can be considered as a sampling universe (Morris 1955). Initial sampling may be done to exclude microhabitats that are difficult to sample and contain relatively few species unless an exhaustive sampling program is pursued. Critical or poorly known habitats within ecosystems that are being lost should be of particular importance. For example, old-growth forests -- canopy, snags, coarse woody debris (standing and fallen), soil, and wetlands.

3. Select sampling units. Depending on the biology of the target species and the habitats, the sampling unit can be a pitfall trap, a sticky trap, a beating sheet or a sweeping net. Efforts should be made to use the same type of sampling unit throughout the survey. The size of the sampling units should be appropriate for the target species (Southwood 1978).

4. Chose field sampling schemes. Many arthropod species can not be sampled directly. Instead, a sampling device such a trap, a sweeping net or a beating sheet is used. Thus, the primary sampling unit is not an individual organism, but a sampling device. Simple random sampling is rarely used as it is not feasible to arrange sampling devices randomly in the field. However, sampling units can be arranged systematically in a habitat.

5. Identify and process specimens. Insufficient resources and taxonomic specialists impede any survey; this is most chronic when dealing with terrestrial arthropods (see Kosztarab and Schaefer 1990). Identification keys to most arthropods of British Columbia do not exist, and therefore most specimens will have to be sent out to relevant systematists. Correct specimen preparation, labeling and establishing an identification network must be considered before the sampling program is initiated.

6. Ensure specimen data from the survey are made available. Recorded data should follow the format of the Canadian Heritage Information Network (CHIN). Specimen records in this database typically contain: elevation, UTM co-ordinates, date, collector, and habitat descriptions. Collection information and all specimen-specific information should also be recorded.

7. Be aware that sampling for rare species requires unique sampling strategies. Methods such as adaptive cluster sampling may be applied (Schreuder *et al.* 1993). Often, an increase in the number of traps increases the chance of capturing rare species.

3.3.1 Sampling schemes

Systematic sampling

In a systematic sampling scheme, sampling units are arranged or ordered in a systematic manner. For example, 20 traps can be arranged in five rows in a old growth stand, with four traps in a row at approximately equal distance apart. Such a scheme has the advantage of spreading out the sampling units over the entire sampling universe, but caution should be taken to avoid spatial autocorrelation.

Stratified sampling

When terrestrial arthropods are to be sampled in a very large area, for example, an old growth forest composed of both pure and mixed old growth stands, the sampling universe (the forest) may be stratified to obtain more precise information as the distribution and

abundance of arthropods are expected to vary considerably between pure and mixed stands. Stratified sampling can significantly reduce variance between strata and is very useful when a survey is to be carried out along some environmental gradient.

Random sampling

If traps can be placed in a habitat so that all habitat units have the same chance of being selected, the sampling procedure is considered random sampling. Two methods have been used to randomly place sampling units to estimate insect populations: one involves random selection for a list of all possible sampling units (e.g. all possible host trees within an area) and the other operates by random coordinate selection (Legg and Yearcan 1985). Generally, it is difficult to use random sampling for arthropods in a field setting.

Removal sampling

The number of species and individuals captured are sometimes too many to count. If a proportion of the organisms in a sampling unit is removed sequentially, the decline in catch size may be used to estimated the entire population size (Seber 1982).

3.4 Sampling Techniques

Arthropods (mainly insects, mites and spiders) have several biological features that predispose them to diversity in response to environmental heterogeneity (Southwood 1978). The ability of arthropods to exploit a variety of habitats coupled with their diversified behaviour means that few traps are equally efficient for the capture of different groups. Owing to the diverse nature of the taxa to be surveyed, and their varied habits and life cycles, no single sampling technique can be used for inventories of rare or endangered invertebrates. Depending on the taxa involved, usually more than one sampling technique should be used in a biodiversity survey. The entomological literature comparing efficiency of different traps and survey techniques is large. However, most techniques are simple variations on a common design. Comprehensive inventories should incorporate a variety of these sampling techniques to meet the requirements of accurately recorded arthropod faunas.

Table 1 attempts to summarize the sampling techniques that are most easily used, and the relevant taxa that can be collected by each technique. A comprehensive, but somewhat outdated review of the major techniques is given by Martin (1977), and most are reviewed by Cannings (1992). Trap responses of flying insects and the influence of trap design on capture efficiency is superficially reviewed by Muirhead-Thompson (1991). Other sampling methods, such as fogging for canopy invertebrates (see Erwin 1983), etc., are available, but are costly to set up and operate. In certain special habitats, such as peat bogs, springs, and caves, special techniques are required.

3.5 Sample Replication

Sample replication (temporal) is directly related to arthropod activity. Because the phenology of species are very variable, even within a single taxon, sampling must be carried out for an extended period, usually over the whole active season (e.g., especially important in "short-lived" univoltine species). Activity is directly related to climatic conditions, and geographic location. These must be factored into collection procedures. Seasonal variation requires sampling over the entire period of activity and must take life cycle duration into account. These times will vary depending on latitude and climatic factors, but in the ecoregions and

ecosections of special interest in the south of the province, they will extend from April to October. For example, the typical activity span for the major arthropod groups in the Carmanah Valley, Vancouver Island, runs from April to November inclusive (Winchester 1992). Efforts should be directed to use time as a variable in examining the variability of trap catches.

3.6 Description of Trap Types

3.6.1 Macroscale Sampling

Flight intercept trap

The most common passive, flight-intercept trap is the Malaise trap (Figure 1). The one used in this inventory is modeled after the description given by Townes (1962). For a complete review on Malaise traps see Steyskal (1981). Malaise traps work on the principle that many flying insects fly to the highest and brightest point (collecting head) when they encounter an obstacle (trap panels). This is a particularly effective method for collecting Diptera and Hymenoptera. A liquid-filled trough or pitfall should be placed along the base of the central wall to collect species that drop when they hit a barrier (e.g., many Coleoptera).

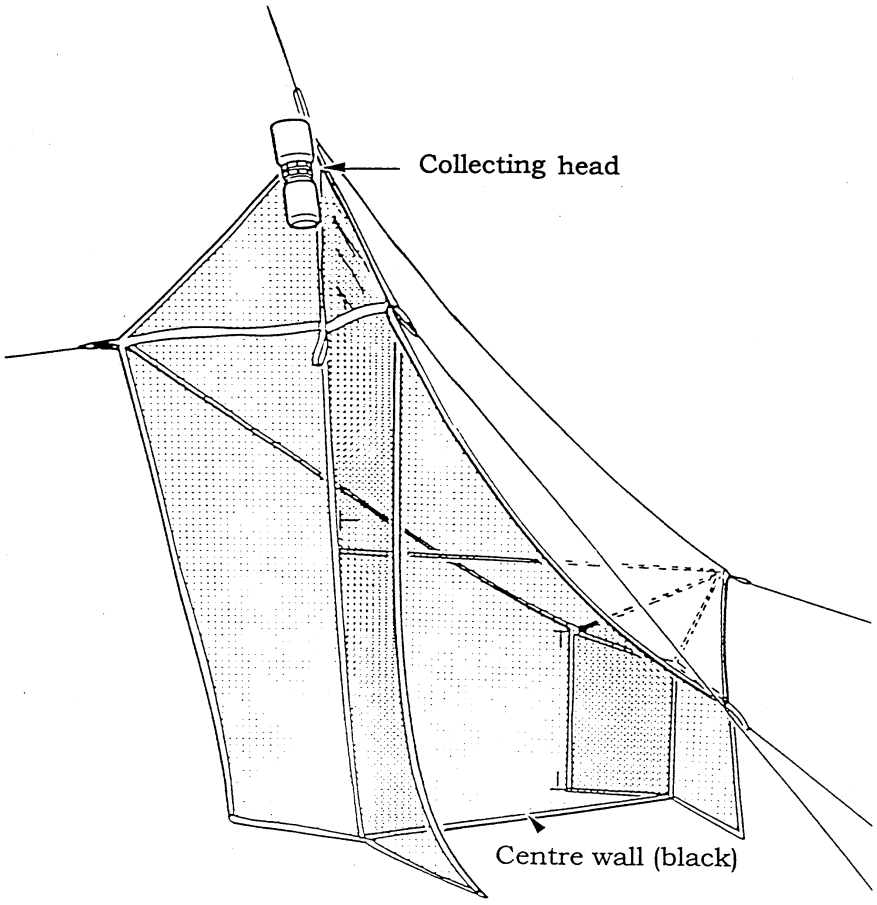

Figure 1. Design and construction of a Malaise trap. (From Martin 1977).

Length (center wall) 1.4 m; height (collection head) 1.8 m; volume of collection jar 1.75 L (Winchester 1992).

Pan traps/window traps

Pan traps are simple collecting vessels (e.g., plastic trays), filled with liquid (e.g., brine solution) that are placed flush with the ground. They mainly serve to capture ground-dwelling and low flying arthropods, including Arachnida, Coleoptera, and Orthoptera. A window trap incorporated above the pan trap enables collection of low flying arthropods, such as Coleoptera, that drop when they encounter an object. A cover should be placed above the window to protect the catch from rain. The pan can be painted yellow to attract several taxa. The details of this trap combination are shown in Figure. 2.

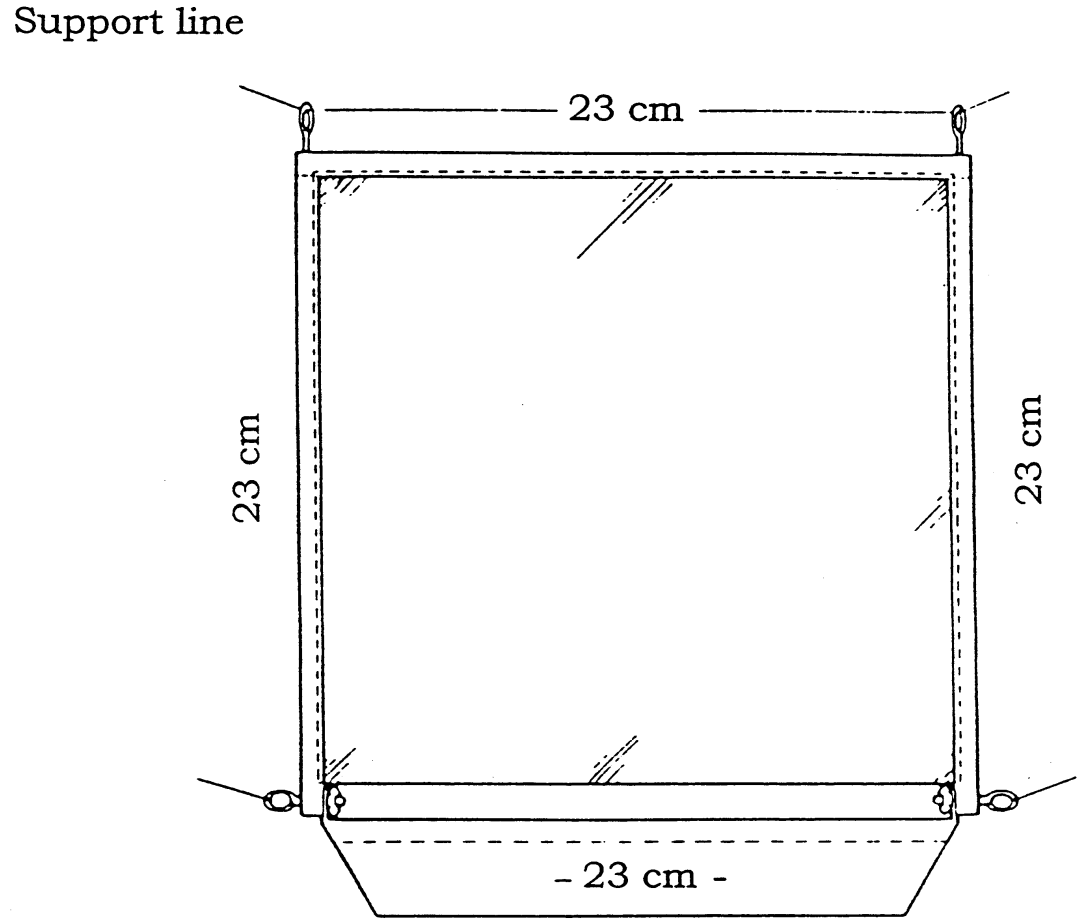

Figure 2. Design and construction of a standard window trap. (From Martin 1977).

Trap width and length should match pan trap specifications (e.g., minimum pan trap size: 23 x 23 cm).

Pitfall traps

Pitfall traps are containers (e.g., jars, plastic bottles, tins) that are buried so that the rim of the collecting container is flush with the surface of the ground. They mainly serve to capture ground-dwelling arthropods (similar to pan traps). A cover should be placed about two cm above the ground directly over the trap to exclude the rain, and a one inch (25 mm) mesh (e.g., hexmesh) screen placed flush with the opening to exclude small mammals and amphibians. The details of the trap are shown in Figure 3. Multiple pitfall traps can be used and connected by "drift fences". Aluminum flashing up to 30 cm high can be used to connect pitfalls. The details of this trap combination are shown in Figure. 4.

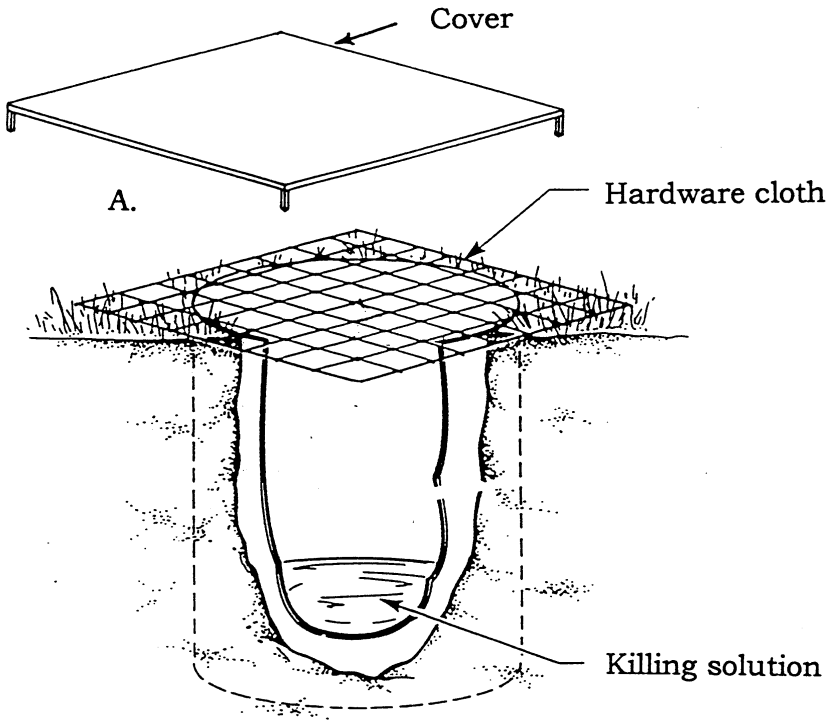

Figure 3. Design of a standard pitfall trap (from Martin 1977).

Trap volume should be 450 ml, and the diameter of opening a minimum of 8 cm.

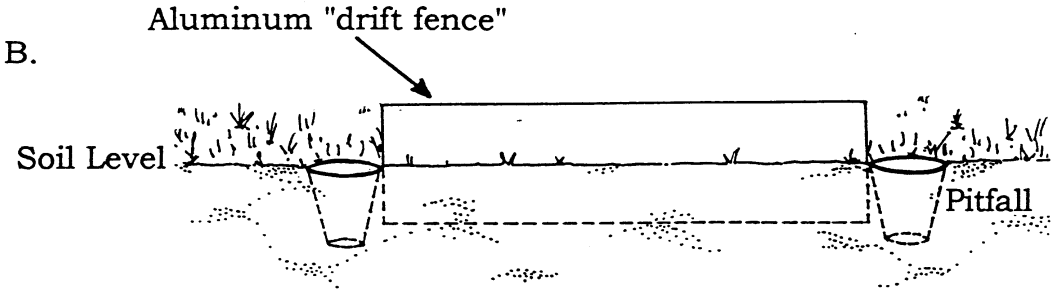

Figure 4. Multiple pitfall traps.

Cores - Berlese (Tullgren) funnels

Substrate cores are used principally to sample for soil arthropods. A simple bulb planter can be used to collect samples to a depth of five cm. The samples should then be run through an extraction funnel (Figure 5). Arthropods avoid the heat source (light bulb), and are driven down a funnel into a collecting vessel containing a preservative.

Berlese funnels can also be used to extract arthropods from litter or moss samples. Surface litter should be collected and first sieved to sort out large and mobile arthropods (e.g., arachnids, beetles). Contents are then placed into a garbage bag for transport to lab and then run through a Berlese funnel. Very small arthropods can be extracted using a technique described by Besuchet *et al*. (1987).

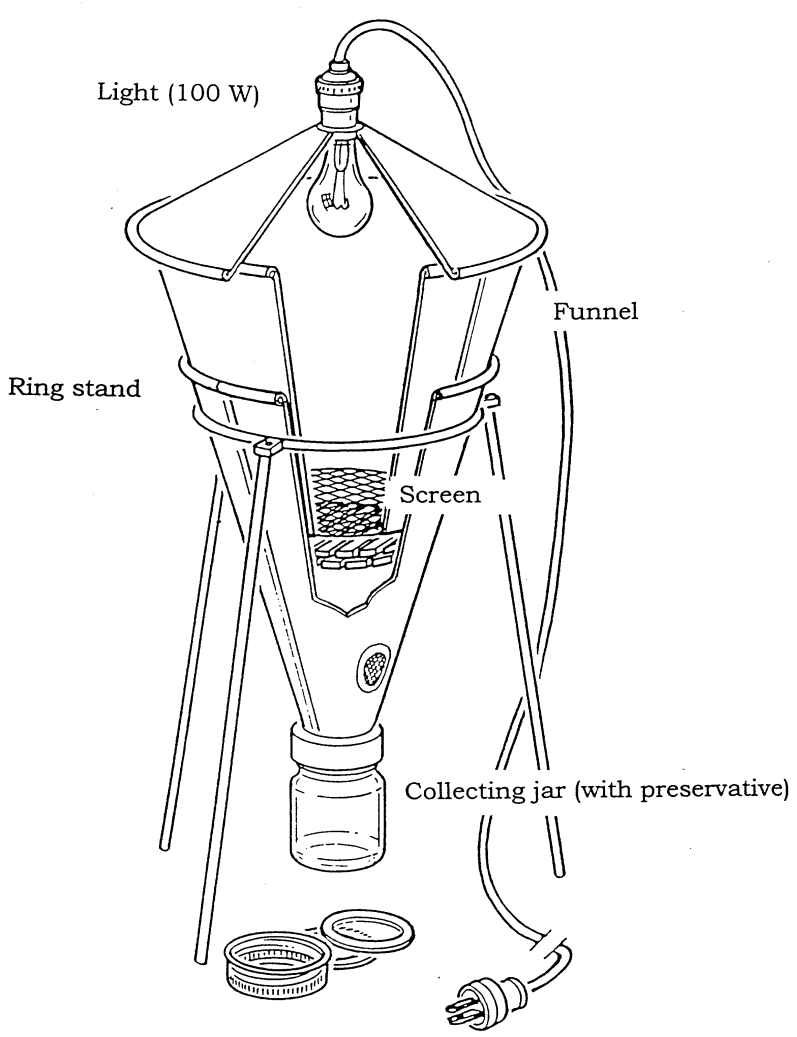

Figure 5. A single Berlese funnel (from Martin 1977).

Diameter of funnel should be at least 30 - 38 cm. A series of 12 funnels can be used simultaneously in a ventilated funnel box (Winchester 1992).

Light traps

Terrestrial light traps are effective for trapping night-active insects, primarily Lepidoptera. Typically, mercury-vapor lamps (Figure 6) are used. However, black-light or other lamp sources high in ultraviolet emissions can be used, even white light (e.g., Coleman lantern) produces good results. There are portable light sources, with battery packs or generators, that enable light traps to be run when an electrical source is unavailable (see Gerber *et al*. 1992).

Two principal methods of collecting samples from light traps in the field exist. They are: (a) a white sheet placed on the ground or suspended in front of the light source (any insects that are attracted to the light are then manually collected from the sheets), and (b) a simple funnel trap placed below the light source. Insects attracted to the light strike the funnel or baffles and fall into the bottom of the trap where they can be manually removed and processed.

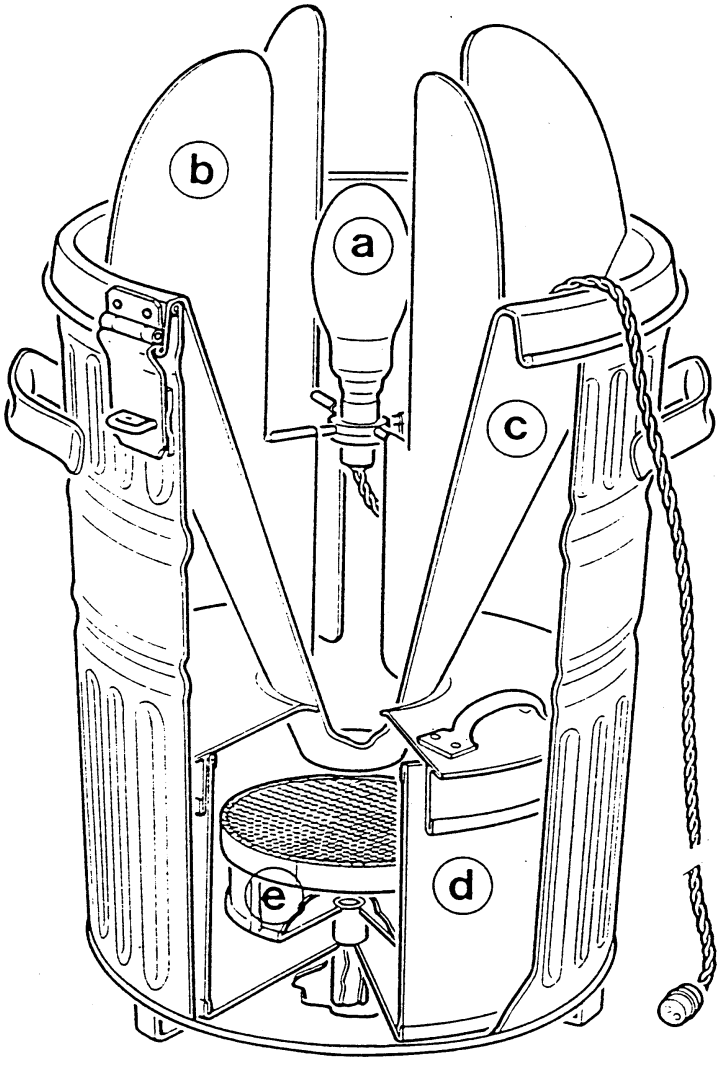

Figure 6. A mercury vapour trap (from Martin 1977).

(a) 125 W 200-220 V Osram mercury-vapour globe, (b) four metal baffles, (c) metal funnel, (d) metal inner killing chamber, (e) rain drain with tube leading to the outside of the trap.

3.6.2 Microscale Sampling

Manual Collecting (netting and chasing)

Manual collecting is an excellent method for collecting many arthropods that are closely associated with vegetation, or particular microhabitats. The methodology for this technique is simple: the collector uses a light weight aerial net and catches any arthropod that can be tracked down! Data can be recorded as catch per unit effort. A reasonable sample is five hours of fine weather collecting, once every two weeks. This method provides a comparison with the trapping techniques to evaluate trap efficiency (presence/not detected).

Coddington *et al*. (1991) provide an excellent procedure to quantify manual searching (Table 2). A collector can use two stopwatches which would enable two or three methods to be used simultaneously - two hour-based samples, and a technique based on counts or area. Using more than one method at a time provides for a much more efficient use of time by maximizing collecting effort. Being able to switch is important because this maximizes the collecting effort: it helps maintain efficiency and interest in collecting, and tends to inhibit the natural tendency of a collector to quit when collecting is poor. These methods are presented below.

Table 2. Initial matching of collecting methods against classification of microhabitats for sampling of arthropods (Coddington *et al*. 1991).

Traditional Methods	**Microhabitats**	
Hand searching	1. Herb layer	
Beating trays	2. Shrub layer	
Sweep nets	3. Tree bark/surface and beneath	
Pitfall traps	4. Leaf litter	
Litter sifting/extraction	5. Big holes (burrows, hollows, streambanks)	
Bark/log fragmentation	6. Little holes (tubes in soil)	
Splashing and drowning	7. In/under logs, rocks	
Looking up: Hand searching	accesses 1-3 above	Sampling Unit = 1 hour
Looking down: Hand searching	accesses 4-7 above	Sampling Unit = 1 hour
Beating foliage: Beating tray	accesses 1, 2 above	Sampling Unit = 20 beats
Litter sifting: Funnel/sheet	accesses 4 above	Sampling Unit = 2 m^2

Searching

a) **Looking up.** Hand collecting and use of an aspirator (Figure 7). The collector searches along a transect collecting arthropods from any vegetation above knee height. Distance covered should be recorded. This correlates to collecting while walking (Coddington *et al*. 1991).

b) **Looking down.** Hand collecting, as above; however, the collector searches along a transect collecting arthropods below knee height. Distance covered should be recorded. This would include searches of soil, leaf litter, forest floor debris and low vegetation.

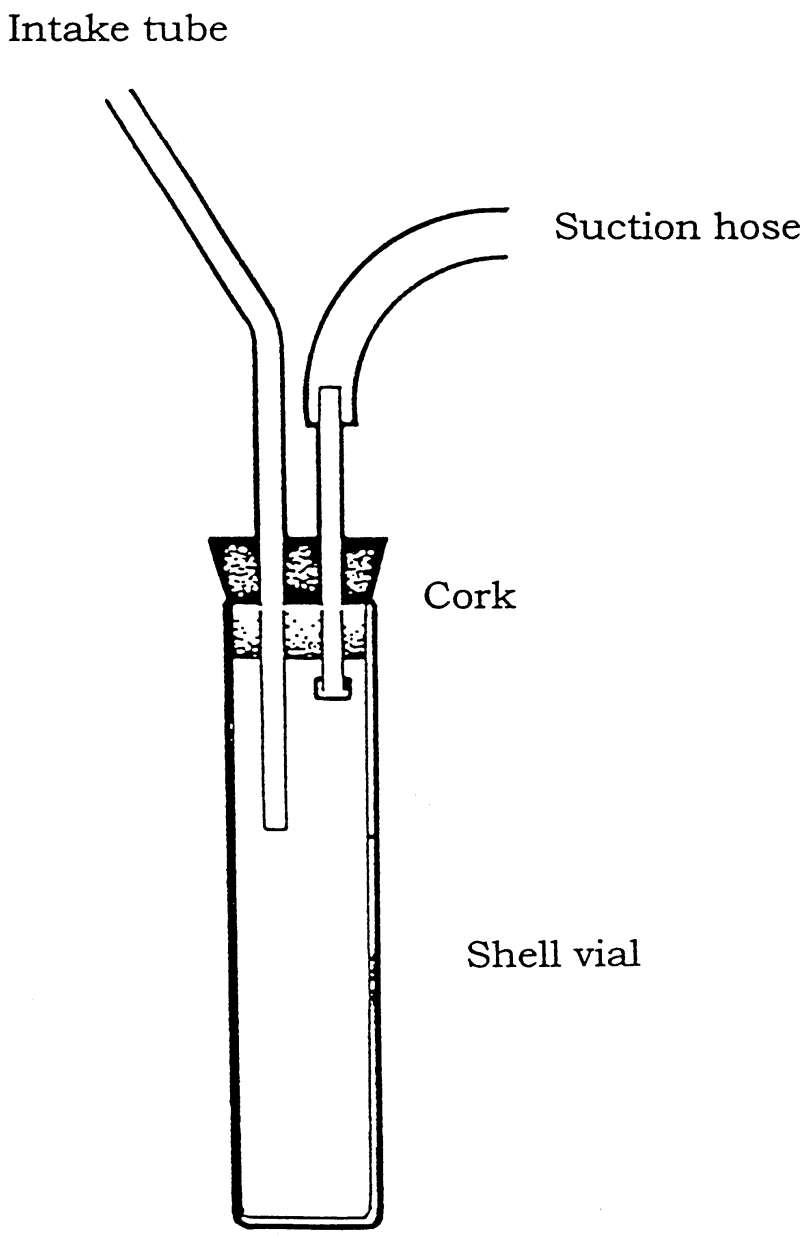

Figure 7. A mouth-operated vial aspirator (from Martin 1977).

Beating

A standard tray (ca. 1 m^2) or beating sheet (Figures 8 and 9) is placed beneath a suitable unit of vegetation (e.g., shrub, branch, etc.). The collector then "beats" the vegetation and collects all the arthropods that drop into the tray when disturbed. Twenty beats (or until no arthropods drop) constitute one sample. Between beating and collecting falling insects, it may take about an hour to collect one sample.

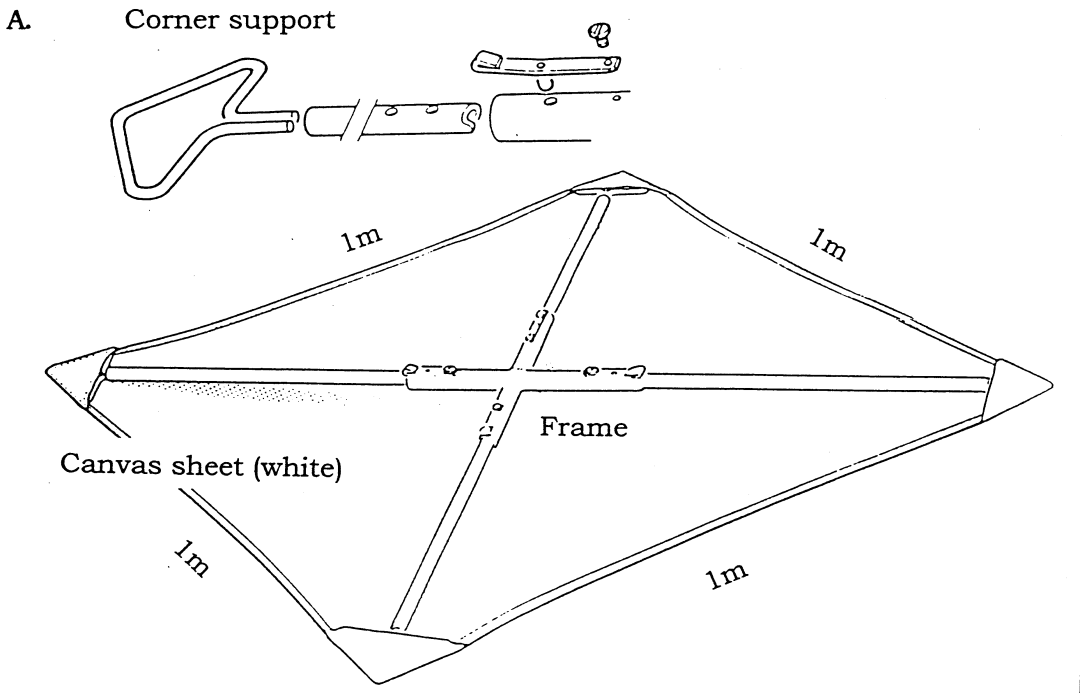

Figure 8. Design and frame of an "old-fashioned" beating sheet (from Martin 1977).

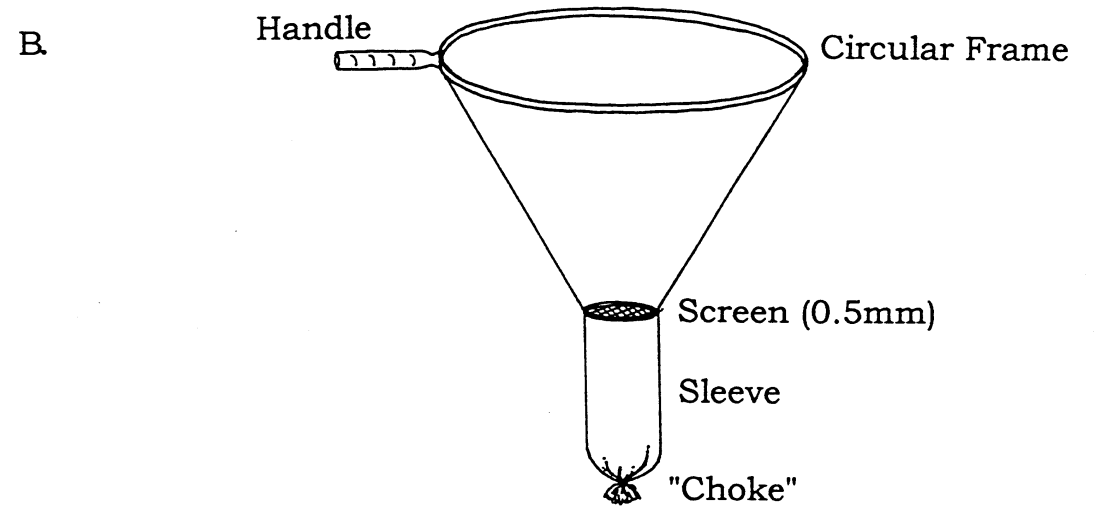

Figure 9. Design of an advanced beating sheet (Masner pers. comm.).

Litter sifting

Large litter and soil arthropods (e.g., Coleoptera, Chilopoda) can easily be gathered by delimiting a 1.0 m^2 sample area and sequentially removing the litter/soil layer to a desired depth (e.g. 6 cm). The litter and soil can be processed through a series of sieves below which a collecting tray is placed (e.g., white tray). Larger arthropods can simply be collected from the sieves and tray and the soil/litter residue can be extracted for smaller arthropods using the procedure outlined for Berlese (Tullgren) funnels or the procedure outlined by Besuchet *et al*. 1987.

Sweeping

Sweep netting is one of the most commonly and widely used procedures used to sample arthropods on vegetation (Figure 10). Taxa which sit high on vegetation or do not fall off when disturbed and may be poor fliers might be most effectively sampled using this method. A modification of the standard sweep net noted by Milne (1993) incorporates the use of a detachable bag which improves the expediency of this technique in the field. If the samples cannot be processed within a short-time of capture then the detachable bags should be kept in a cooler until the trap contents can be sorted. A total of 20 sweeps constitutes one sample.

The sample design (census methodology) and trap specifics for these techniques are described below. These information can also be supplemented by referring to "Terrestrial Arthropod Biodiversity: Planning a study and recommended sampling techniques", a brief prepared by the Biological Survey of Canada (Terrestrial Arthropods), 1994.

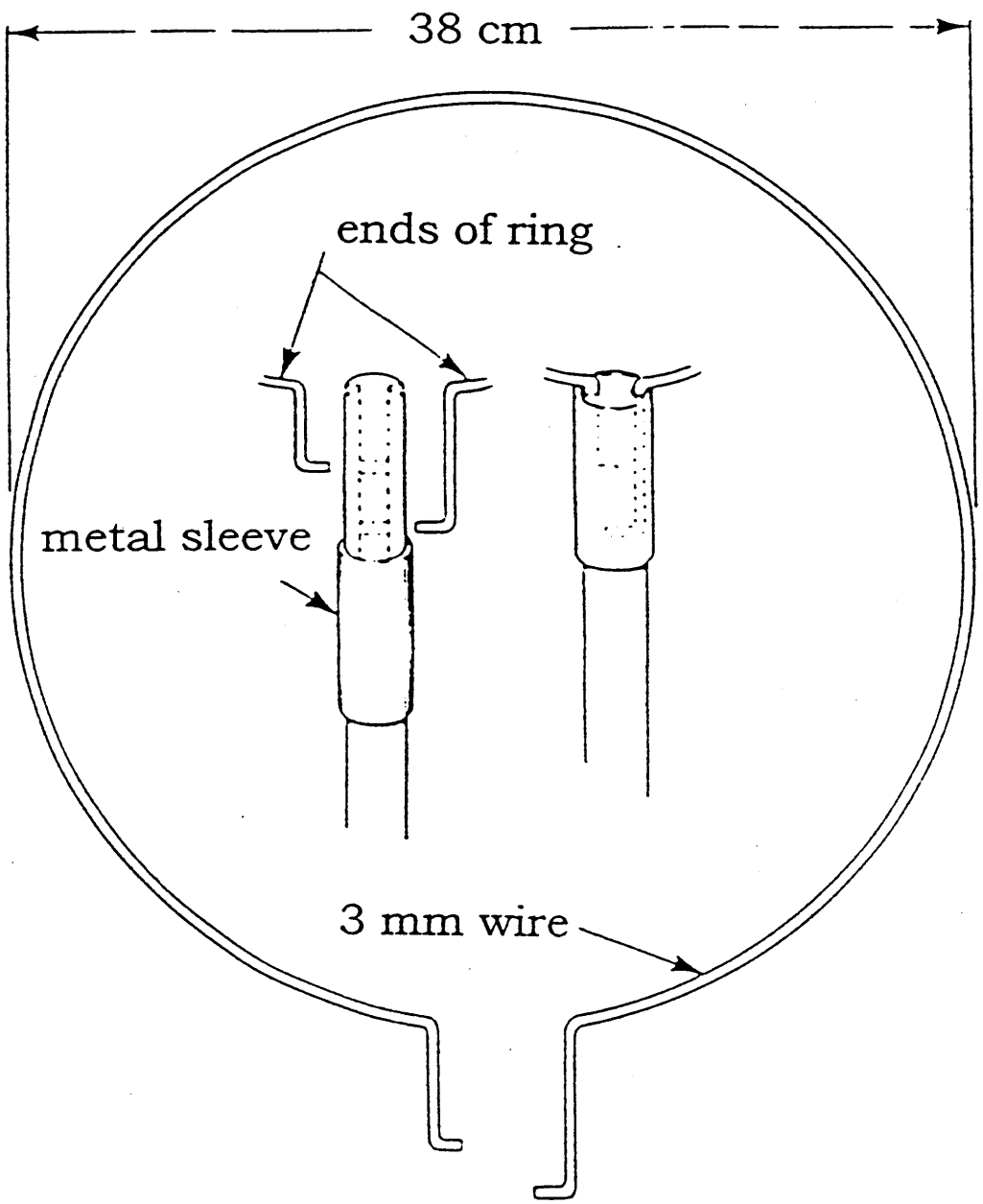

Figure 10. Details of insect sweep net, showing detachable wire ring and attachment to handle (from Martin 1977).

3.7 Trapping Protocol

3.7.1 Macrohabitat Sampling

Flight interception trap (Malaise)

- Trap dimensions: Refer to Figure 1, and Townes (1962).
- Minimum five traps in each macrohabitat block and increase the number of traps if necessary (e.g. five capture stations or samples per macrohabitat block).
- Place traps systematically along a transect or within a grid. Traps should be positioned so that they maximize the use of habitat edges or corridors. Also, take advantage of maximum light conditions by installing the traps so that the collecting heads face south.
- Traps should be separated by a minimum of five meters.
- Traps should be cleared every two weeks; however, a shorter interval may be used.
- Preservative (collecting head): 800 ml of 95% EtOH; add six drops of propylene glycol (Glycol-P).
- NOTE: If traps run dry of preservative, they should be emptied daily.

Pan/window trap

- Trap dimensions: Refer to Figure 2.
- Minimum six traps in each macrohabitat block and increase the number of traps if necessary (e.g. six capture stations or samples per macrohabitat block).
- Traps should be placed systematically along a transect or within a grid. Traps should be positioned so that they maximize the use of habitat edges or corridors.
- Traps should be separated by a minimum of five meters; however, they can coincide with placement of the Malaise traps if they are separated from these traps by two meters.
- Traps should be cleared every week, the collecting interval should correspond to the Pitfall trap clearings.
- Preservative: 50:50 Glycol-P with distilled water (fill trap to the **1/4** mark).

Pit-fall trap

- Trap dimensions: Refer to Figures 3 and 4.
- Minimum six 450-ml traps in each macrohabitat block. The number of traps may be increased depending on species abundance, habitat variability and survey precision requirements (e.g. six capture stations or samples per macrohabitat block).
- Traps should be placed systematically along a transect or within a grid. Traps should be separated by a minimum of five meters; however, they can coincide with placement of the Malaise traps if they are separated from these traps by two meters, and from pan/window traps by five meters.
- Traps should be cleared every two weeks; the collecting interval should correspond to the pan/window trap clearings.
- Preservative: 50:50 Glycol-P with distilled water (fill trap to the 3/4 mark).

Cores - Berlese (Tullgren) funnels

Substrate cores

- Minimum five cores from each habitat block (e.g. five capture stations or samples per macrohabitat block).
- Cores should be taken systematically along a transect or within a grid. Random sampling without replacement should be used; there is no need to incorporate distances between samples.
- Cores should be collected once a month.
- Cores can be stored in separate polyethylene bags and kept in a cooler. Samples should be kept at 5 °C in the lab until they are ready for extraction.
- Volume displacement and/or dry weights should be taken for each core.

Extraction

- Berlese funnel design: Refer to Figure 5.
  - Samples should be extracted for 48 hours, or until the core sample is completely dry.
  - Samples should be collected into 75-80% EtOH.
- Surface litter sifting
  - Minimum of five l m x l m quadrats should be used to collect surface litter, (e.g. five capture stations or samples per macrohabitat block).
  - Place quadrats randomly along a transect or grid (random sampling without replacement).
  - Collect litter from each quadrat into large garbage bags - litter should not exceed five to nine litres
  - Initial sieving in the field should be done to remove large and mobile arthropods. Sieving should be done over a white sheet or tray.
  - Extraction procedure should follow the protocol outlined above.
  - Litter samples should be collected once a month.

Light traps

- Trap design: Refer to Figure 6.
- A single light trap should be set up in each habitat block (e.g. one capture station or sample per macrohabitat block).
- Traps should be run once every week between dusk and dawn. Catch will be dependent on weather: lower catch in poor weather, hot humid moonless nights provide ideal conditions to maximize catches.

3.7.2 Microhabitat Sampling

Searching

Looking up

- Aspirator details: Refer to Figure 7.
- Place a transect in each habitat block.
- Collect for one hour (use a stopwatch). Record distance traveled. Repeat collection procedure at three intervals (early, mid, late) each day. (e.g. three samples per macrohabitat block). Frequently change shell vials (from aspirator); store vials in a cooler until sorting can be carried out.
- Number of sample days is not fixed and should be predetermined.

Looking down

- Repeat "looking up" procedure listed above (except ‘look down’ below knee level).

Beating

- Beating sheet details: Refer to Figures 8 and 9.
- The unit of vegetation to sample should be chosen randomly or systematically from a group of suitable vegetation types. This sample unit may be chosen from a transect or a grid.
- At each sample unit (e.g., branch, bush), beat 20 times or until no more arthropods drop.
- Arthropods can be collected from the beating sheet with an aspirator. However, this method is highly inefficient for most mobile insects which are able to avoid the aspirator. It is recommended that the beating sheet design recommended by Masner be used here, all insects are collected at the bottom of the sleeve and can be emptied into a container by simply loosening the "choke".
- A minimum of 10 sample units from each habitat block should be taken (e.g. 10 trees are beaten within each macrohabitat block).

Sweeping

- Sweep net design: Refer to Figure 10.
- Each sample station should be selected randomly, or systematically along a transect or grid. Sampling without replacement should be used.
- Twenty sweeps (one at each step) constitute one sample.
- Minimum of 5 samples from each habitat block.
- Detachable bags (Figure 11) should be kept in a cooler until sorting can be carried out. The contents of the bag can be emptied directly in a killing jar, or a container with preservative (usually 75% EtOH).

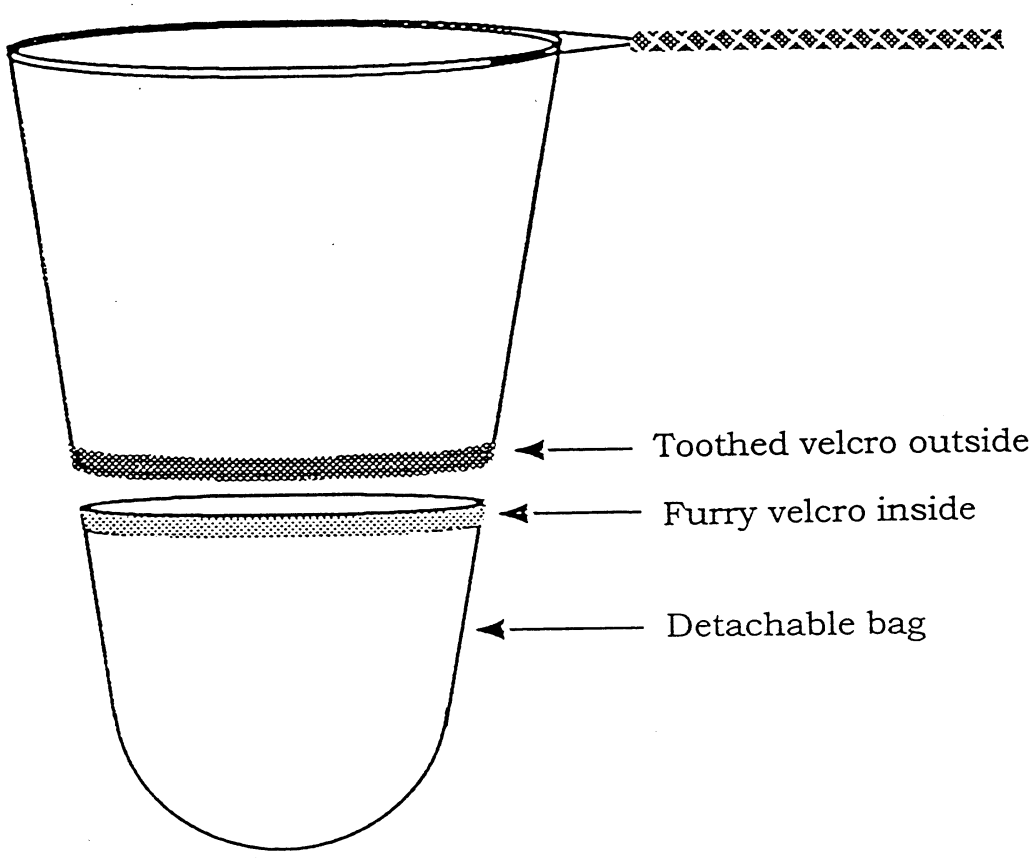

Figure 11. Diagram of sweep net showing detachable bag (from Milne 1993).

3.8 Data Forms and Labels

The table below outlines the type of surveys that are used for inventorying terrestrial arthropods at the presence/not detected (possible) intensity. These survey methods have been recommended by biologists and approved by the Resources Inventory Committee.

Table 3. Types of inventory surveys, the data forms needed, and the level of intensity of the survey.

Survey Type	Forms Needed	Intensity
All Macrohabitat Sampling Surveys: • Flight intercept trapping (Malaise) • Pan /Window trapping • Pitfall trapping • Cores (Berlese) Light trapping	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form • Animal Observation Form- Terrestrial Arthropods • Wildlife Survey Collection Label	• PN
All Microhabitat Sampling Surveys: • Manual Collecting (netting & chasing) • Searching (up / down) • Beating • Sweeping • Litter Sifting • Dipnet-sweeping • Dipnet-shuffling	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form • Animal Observation Form- Terrestrial Arthropods • Wildlife Survey Collection Label	• PN

* PN = presence/not detected (possible)

Insect Labels. Insect labels must be standardized. It will be necessary to discuss the format of the collection labels with the agency at which they will be deposited. At an absolute minimum, the initial label (prior to classification) should include collector name, date, location name, UTM or Lat/Long coordinates and a unique sample code (observation number). However, an excellent discussion of label preparation for insect specimens to be submitted for identification is available in Appendix A. This provides a better model for how specimens should be labelled.

3.9 Statistical Data Analysis

Some common measures and estimates

Relative abundance or species density. The average number of individuals per sampling unit:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (1.0)$$

where: x_i = the number of individuals in sampling unit i and n = the number of sampling units.

Species proportion. The proportion of species A in sampling unit i:

$$p_i = \frac{a_i}{m_i} \qquad (2.0)$$

The proportion of species A in n sampling units is defined as:

$$p = \frac{\sum_{i=1}^{n} a_i}{\sum_{i=1}^{n} m_i} \qquad (3.0)$$

where: n=number of traps used in a survey sampling, a_i=number of individuals belonging to species A in sampling unit i, m_i=number of all individuals in sampling unit i.

Species richness. The average number of species per sampling unit:

$$\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n} \qquad (4.0)$$

where: y_i = the number of species in sampling unit i and n = the number of sampling units.

Species dominant. This is estimated using the Berger-Parker equation:

$$d = \frac{N_{\max}}{N_{tot}} \qquad (5.0)$$

where: N_{max} = the number of individuals of the most abundant species and N_{tot} = the number of individuals of all species (Magurran 1988).

Species diversity. This is measured using Hurlbert's probability of interspecific encounter (Hurlbert 1971):

$$PIE = \sum_{i=1}^{3} (n_i / n)\left[(n - n_i) / (n - 1)\right] \qquad (6.0)$$

where: n=number of all individuals in the sample, n_i=number of individuals of a species in the sample and s=number of species.

There are many approaches to calculating species diversity; for a more detailed discussion consult Krebs (1989, 1998). The new computer programs of Krebs (1989, 1998) or *Krebs for windows* software will also calculate many of these quantities. See manual no. 1, *Species Inventory Fundamentals* for more details.

Variance/mean ratio. Small value of $s^2 / \bar{x}$ ratio indicates that the variance (s^2) is small compared to the mean ($\bar{x}$). This can be used as a index to compare alternative traps.

Coefficient of variation. This is defined as the sample standard deviation (s) expressed as a percentage of the sample mean, CV=100 $s / \bar{x}$. CV is often used to compare the variability of catches between different types of traps.

Spatial distribution

The main objective of quantitatively describing spatial distribution is that it will allow an estimate of variance of insect counts at different insect densities. Using estimates of variance, the optimal sample sizes (of insect counts) to be used for analysis (i.e., hypothesis testing) can be estimated. These are useful calculations because counting insects is tedious and time consuming so it is best to optimize the sampling strategy.

Spatial distribution is generally analyzed for major species only.

The mean-variance relationships described by Iwao (1968) and Taylor (1961) have long been the major approaches for arthropod spatial distribution, especially insects (Southwood 1978, Kuno 1991). Based on evidence from 24 data sets, Taylor (1961) showed that many animal species were distributed non-normally and that the relationship between the mean ($\bar{x}$) and the variance (s^2) can be described as:

$$s^2 = a\bar{x}^b$$

(7.0)

The logarithmic form of the relationship is:

$$\log\left(s^2\right) = b\log\bar{x} + \log a$$

(8.0)

where: slope b = a species-specific measure of aggregation with a value of: <1 for a uniform distribution, =1 for a random distribution, and >1 for an aggregated distribution.

Essentially, this means that the variance is usually related to the mean in counts of arthropods (as it is in many other animals). Thus, if you have a high count of insects, the variance is high and if you have a low count of insects, the variance is low. Taylor (1961) used this relationship to derive equations 7.0 and 8.0. This is useful for it allows you to predict the amount of variance at different densities of insects. The fundamental relationship between mean and variance is usually exponential (Equation 7.0); however, if you perform a logarithmic transformation of both the mean and variance, the relationship can be changed to a linear one (Equation 8.0). The has an advantage because if you have a series of counts (with different densities), you can estimate *a* and *b* using standard linear regression procedures. To estimate *a* and *b*: (1) log transform each variable, (2) do a simple linear regression with log variance as the *y* variable and log count as the *x* variable (Zar 1996). The estimate of slope is parameter *b* and the estimate of intercept is parameter *a*.

Note that you need a series of samples to estimate *a* and *b*. Therefore a "pilot study" will have to be conducted to get these data to allow parameter estimates. It is not recommended that values of *a* and *b* are used from other studies since insect distributions probably vary between populations (Krebs 1998). Krebs (1989, 1998) and Hayek and Buzas (1997) provide good discussion of this topic. In addition, Krebs (1989, 1998) programs will do the calculation for Taylor's power law and sequential sampling methods described below.

Lloyd (1967) proposed the concept of mean crowding from which Iwao developed a relationship for mean density and mean crowding (Iwao 1968, Iwao and Kuno 1968). This "mean crowding" relationship a slight variation of Taylor's power law (above). It is intended to accommodate insects which exist in a variety of distributions (e.g., clumped, random, *etc.*). However, this method has also been criticized, and many authors have gone back to using Taylor's power law which is less complex (see Krebs 1998). For this reason, it will not be discussed.

Determination of sample size for estimation of species density

Precision or accuracy

The cost involved in sampling arthropods is often substantial, which makes the collection of an excessively large sample unwise. The total number of samples required depends on the desired degree of precision (variance) and accuracy (lack of bias) (Fowler and Witter 1982, Binns and Nyrop 1992). However, zoologists are mainly concerned with precision because accuracy is too difficult to assess due to the biases inherent in arthropod sampling: 1) bias in probability sampling, 2) bias due to use of an estimator invalid for the situation and 3) bias caused by non-sampling error (Fowler and Witter 1982). Precision has been widely described

with the mean-variance relationship proposed by Taylor (1961) and Iwao (1968). It is assumed that low variability is indicative of accuracy. In survey sampling for terrestrial arthropods, the number of samples should be determined prior to the actual sampling. Once a precision level is agreed on, an initial sampling may be conducted to get the sample variance or standard deviation.

In determining the total number of samples necessary to yield a particular precision level, two approaches have been used: the fixed sample size method, and the sequential sampling method (Binns and Nyrop 1992). In the former, the number of samples is determined prior to the actual sampling, whereas in the latter, it is determined repeatedly throughout the study until a given level of precision is reached.

a) Fixed sample size method

Precision of a population estimate can be defined in terms of standard error (SE) of the mean or error margin (SEM). Both can be set to a fixed value or as a fraction of the mean. SEM is calculated by:

$$SEM = t_{a'/2}\left(\frac{s}{\sqrt{n}}\right) \qquad (11.0)$$

where: n = sample size, s = the standard deviation of the sample, t = the value of the t distribution with probability level α' and n-1 degree of freedom.

SEM is simply the tail of a confidence interval. For example, a confidence interval equals the mean ± SEM.

When SEM is expressed as a fraction, d, of the sample mean:

$$SEM = d \times \bar{x} \qquad (12.0)$$

The term d is simply the desired width of the confidence interval, defined as a fraction of the mean (i.e., For a confidence interval of ±20% of the mean, d=.2).

By mathematically manipulating the equation for a confidence interval, it is possible to estimate sample size. This is calculated by :

$$n = \left(\frac{t_{a'/2}}{d\bar{x}}\right)^2 s^2 \qquad (13.0)$$

where: $\bar{x}$ is the sample mean.

This assumes that you are using a t-test or t-distribution to test a hypothesis or calculate a confidence interval. Also, it assumes that you have a good estimate of survey variance (s^2). However, as mentioned previously variance in insect counts will be proportional to the mean

count. Therefore, a better estimate of sample size (for different counts of insects) can be obtained if you replace s^2 with $a\bar{x}^b$, and use Taylor's power law (as described above) to obtain estimates of survey variance at expected insect counts (Equation 14.0).

$$n = \left(\frac{t_{a'/2}}{d} \right)^2 a\bar{x}^{b-2} \qquad (14.0)$$

Note that many power analysis programs exist (as discussed in *Species Inventory Fundamentals, No. 1*) that can be used to explore sample sizes needed to test hypothesised difference between population counts.

The above methods assume a normal distribution of insect counts. This may not be the case. As discussed in *Species Inventory Fundamentals, No. 1*, White and Bennets (1996) offer an alternative test based using a negative binomial distribution which can accommodate a variety of potential distributions.

b) Sequential sampling method

Fixed sample size methods generally require a large number of samples (Fowler and Lynch 1987). In addition, mean density is not known in advance. Sequential sampling methods require, on average, only 40 to 60 percent as many observations as an equally reliable fixed-sample procedure (Fowler and Lynch 1987). Essentially, sequential sampling allows the investigator to stop when s/he reaches a sufficient level of precision.

Wald (1947) laid the foundation for sequential sampling. The sequential sampling plan proposed by Kuno (1969) and modified by Green (1970), based on the Taylor power law (1961), has been widely used in entomology. Equations 15.0 and 16.0 should be calculated incrementally throughout the sampling process. Krebs (1989, 1998) provides a useful and detailed description of sequential sampling, as well as computer programs which will perform these calculations as well (except for estimates of *a* and *b*).

Sampling is stopped when:

$$T_n > \frac{\left(an^{1-b}\right)^{1/(2-b)}}{d^2} \qquad (15.0)$$

or:

$$T_n = \left(\frac{d^2}{anti\log(a)} \right)^{1/(b-2)} n^{(b-1)/(b-2)} \qquad (16.0)$$

where: a = a from Taylor's power law (i.e., y intercept of regression), b = b from Taylor's power law (i.e., slope of regression), d = SEM (as described above), n = number of samples, T_n = the cumulative number of arthropods counted after sampling n sampling units

Binomial sampling

The processing and counting of arthropods can be tedious and time-consuming. Sampling can be made more efficient by substituting binomial counts for complete counts, which is termed binomial sampling (Kuno 1991). In binomial counts, the proportion of insects (of a certain type) is used rather than the count of the insects in the sample. Use the following steps to determine the sample size needed for a desired level of precision.

Define:

P = proportion of a specific insect type in sample (estimated from a pilot study).

Q = 1 - P = proportion of samples without the specific insect type (as estimated from the pilot study)

D = desired margin of error (CI= $p \pm D$). For example, if you want the estimate to be mean ±.02 then *D*=.02

In this case, the samples size (*n*) needed for a desired margin of error (*D*) is simply:

$$n = \frac{t_{\alpha}^2 PQ}{D^2}$$

where: *t* is the student *t* distribution for a given α level (i.e., .05) with *n-1* degrees of freedom.

Note that this formula assumes that the binomial distribution can be approximated using the normal distribution. Therefore, the number of samples used in calculations should be at least 20. See Krebs (1989, 1998) for a more detailed discussion on sampling from the binomial distribution. Many of the power analysis packages mentioned in *Species Inventory Fundamentals* (RIC 1998) will do these calculations.

Some authors have developed methods to estimate mean abundance of insect species based on a model that expresses the relationship between the mean density and the proportion of sampling units containing more than *t* individuals. Kuno (1991) provides detailed discussion.

Glossary

ABSOLUTE ABUNDANCE: The total number of organisms in an area. Usually reported as absolute density: the number of organisms per unit area or volume.

ACCURACY: A measure of how close a measurement is to the true value.

BIODIVERSITY: Jargon for biological diversity: "the variety of life forms, the ecological roles they perform, and the genetic diversity they contain" (Wilcox, B.A. 1984 cited in Murphy, D.D. 1988. Challenges to biological diversity in urban areas. Pages 71-76 *in* Wilson, E.O. and F.M. Peter, Eds. 1988. Biodiversity. National Academy Press, Washington, D.C. 519 pp.).

BLUE LIST: Taxa listed as BLUE are sensitive or vulnerable; indigenous (native) species that are not immediately threatened but are particularly at risk for reasons including low or declining numbers, a restricted distribution, or occurrence at the fringe of their global range. Population viability is a concern as shown by significant current or predicted downward trends in abundance or habitat suitability.

CBCB (Components of B.C.'s Biodiversity) Manuals: Wildlife species inventory manuals that have been/are under development for approximately 36 different taxonomic groups in British Columbia; in addition, six supporting manuals.

DESIGN COMPONENTS: Georeferenced units which are used as the basis for sampling, and may include geometric units, such as transects, quadrats or points, as well as ecological units, such as caves or colonies.

EWG (Elements Working Group): A group of individuals that are part of the Terrestrial Ecosystems Task Force (one of seven under the auspices of RIC) which is specifically concerned with inventory of the province's wildlife species. The EWG is mandated to provide standard inventory methods to deliver reliable, comparable data on the living "elements" of BC's ecosystems. To meet this objective, the EWG is developing the CBCB series, a suite of manuals containing standard methods for wildlife inventory that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species populations.

INVENTORY: The process of gathering field data on wildlife distribution, numbers and/or composition. This includes traditional wildlife range determination and habitat association inventories. It also encompasses population monitoring which is the process of detecting a demographic (e.g. growth rate, recruitment and mortality rates) or distribution changes in a population from repeated inventories and relating these changes to either natural processes (e.g. winter severity, predation) or human-related activities (e.g. animal harvesting, mining, forestry, hydro-development, urban development, etc.). Population monitoring may include the development and use of population models that integrate existing demographic information (including harvest) on a species. Within the species manuals, inventory also includes, species statusing which is the process of compiling general (overview) information on the historical and current abundance and distribution of a species, its habitat requirements, rate of population change, and limiting factors. Species statusing enables prioritization of animal inventories and population monitoring. All of these activities are included under the term inventory.

MONITOR: To follow a population (usually numbers of individuals) through time.

OBSERVATION: The detection of a species or sign of a species during an inventory survey. Observations are collected on visits to a Design Component on a specific date at a specific time. Each observation must be georeferenced, either in itself or simply by association with a specific, georeferenced Design Component. Each observation will also include numerous types of information, such as species, sex, age class, activity, and morphometric information.

POPULATION: A group of organisms of the same species occupying a particular space at a particular time.

PRECISION: A measurement of how close repeated measures are to one another.

PRESENCE/NOT DETECTED (POSSIBLE): A survey intensity that verifies that a species is present in an area or states that it was not detected (thus not likely to be in the area, but still a possibility).

PROJECT AREA: An area, usually politically or economically determined, for which an inventory project is initiated. A project boundary may be shared by multiple types of resource and/or species inventory. Sampling for species generally takes place within smaller, representative Study Areas so that results can be extrapolated to the entire Project Area.

PROJECT: A species inventory project is the inventory of one or more species over one or more years. It has a georeferenced boundary location, to which other data, such as a project team, funding source, and start/end date are linked. Each project may also be composed of a number of surveys.

RANDOM SAMPLE: A sample that has been selected by a random process, generally by reference to a table of random numbers.

RED LIST: Taxa listed as RED are candidates for designation as Endangered or Threatened. Endangered species are any indigenous (native) species threatened with imminent extinction or extirpation throughout all or a significant portion of their range in British Columbia. Threatened species are any indigenous taxa that are likely to become endangered in British Columbia, if factors affecting their vulnerability are not reversed.

RELATIVE ABUNDANCE: The number of organisms at one location or time relative to the number of organisms at another location or time. Generally reported as an index of abundance.

RIC (Resources Inventory Committee): RIC was established in 1991, with the primary task of establishing data collection standards for effective land management. This process involves evaluating data collection methods at different levels of detail and making recommendations for standardized protocols based on cost-effectiveness, co-operative data collection, broad application of results and long term relevance. RIC is comprised of seven task forces: Terrestrial, Aquatic, Coastal/Marine, Land Use, Atmospheric, Earth Sciences, and Cultural. Each task force consists of representatives from various ministries and agencies of the Federal and BC governments and First Nations. The objective of RIC is to develop a common set of standards and procedures for the provincial resources inventories. [See http://www.for.gov.bc.ca/ric/]

SPI: Abbreviation for 'Species Inventory'; generally used in reference to the Species Inventory Datasystem and its components.

STRATIFICATION: The separation of a sample population into non-overlapping groups based on a habitat or population characteristic that can be divided into multiple levels. Groups are homogeneous within, but distinct from, other strata.

STUDY AREA: A discrete area within a project boundary in which sampling actually takes place. Study Areas should be delineated to logically group samples together, generally based on habitat or population stratification and/or logistical concerns.

SURVEY: The application of one RIC method to one taxonomic group for one season.

SYSTEMATIC SAMPLE: A sample obtained by randomly selecting a point to start, and then repeating sampling at a set distance or time thereafter.

TERRESTRIAL ECOSYSTEMS TASK FORCE: One of the seven tasks forces under the auspices of the Resources Inventory Committee (RIC). Their goal is to develop a set of standards for inventory for the entire range of terrestrial species and ecosystems in British Columbia.

YELLOW-LIST: Includes any native species which is not red- or blue-listed.

References

Besuchet, C., D.H. Burckhardt and I. Lobl. 1987. The "Winkler/Moczavski" eclector as an efficient extractor for fungus and litter Coleoptera. Col. Bull. 41(4):92-394.

Biological Survey of Canada. 1994. Terrestrial arthropod biodiversity: Planning a study and recommended sampling techniques. Supplement to the Bull. Ent. Soc. of Canada pp. 1-33.

Binns, M.R., and J.P. Nyrop. 1992. Sampling insect population for the purpose of IPM decision making. Ann. Rev. Entomol. 37:427-453.

Cannings, S. 1992. Arthropods - Where diversity is really at. Pages 43-48 *in* L.R. Ramsay, ed. Methodology for monitoring wildlife diversity in B.C. forests. BC Environ., Wildl. Br., Victoria, BC.

Coddington, J.A., C.E. Griswold, D.S. Davila, E. Penaranda and S.F. Larcher. 1991. Designing and testing sampling protocols to estimate biodiversity in tropical ecosystems. Pages 44-60 *in* C.E. Dudley, ed. The unity of evolutionary biology: proceedings of the fourth international congress of systematics and evolutionary biology. Dioscorides Press, Portland, OR.

Danks, H.V. (ed.). 1979. Canada and its insect fauna. Memoirs of the Entomological Society of Canada, No.108.

Disney, R.H.L., Y.Z. Erzinclioglu, D.J. de C. Henshaw, D. Howse, D.M. Unwin, D.M., P. Withers and A. Woods. 1982. Collecting methods and the adequacy of attempted fauna surveys, with reference to the Diptera. Field Studies 5:607-621.

Dunn, M. 1989. Bibliography of information on pitfall trapping. Young Entomologists Association Quarterly 6:41-42.

Entomological Society of Canada. 1992. Resolution concerning study of biodiversity of terrestrial arthropods. Can. Biodiversity 2:2324.

Erwin, T.L. 1983. Tropical forest canopies: The last biotic frontier. Bull. Entomol. Soc. Am. 30:14-19.

Fowler, G.W., and A.M. Lynch. 1987. Sampling plans in insect pest management based on Wald’d sequential probability ratio test. Environ. Entomol. 16:345-354.

Fowler, G.W., and J.A. Witter. 1982. Accuracy and precision of insect density and insect estimates. The G. L. Entomol. 15:103-117.

Gerber, G.H., J. Walkof and D. Juskiw. 1992. Portable, solar-powered charging system for blacklight traps. Can. Ent. 124:553-554.

Gerrard, D.J., and H.G. Chiang. 1970. Density estimation of corn rootworm egg population based upon frequency of occurrence. Ecology 51:237-245.

Green, R.H. 1970. On fixed precision level sequential sampling. Res. Popul. Ecol. 12:249-251.

Green, R.H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. John Wiley and Sons, New York, NY.

Hamilton, A.L. 1991. In search of common ground. Can. Biodiversity 1:25-27.

Hammond, P.M. 1990. Insect abundance and diversity in the Dumoga-Bone National Park, N. Sulawesi. Pages 197-255 *in* W.J. Knight and J.D. Holloway, eds. Insects and the Rain Forests of South East Asia (Wallacea). Royal Entol. Soc. London.

Hayek, L.C., and M.A. Buzas. 1997. Surveying Natural Populations. Columbia Univ. Press, New York, NY.

Hoekstra, T.W., T.F.H. Allens and C.H. Flather. 1991. Implicit scaling in ecological research. BioScience 41:148-154.

Iwao, S. 1968. A new regression method for analyzing the aggregation pattern of animal populations. Res. Popul. Ecol. 10:1-20.

Iwao, S., and E. Kuno. 1968. Use of regression mean crowding on mean density for estimating sample size and the transformation of data for the analysis of variance. Res. Popul. Ecol. 10:210-214.

Kosztarab, M., and C.W. Schaefer. 1990. Systematics of the North American insects and arachnids: Status and needs. Virginia Agricultural Experimental Station, Information Series 90-1.

Krebs, C.J. 1989. Ecological Methodology. Harper Collins, New York, NY.

Krebs, C.J. 1998. Ecological Methodology. 2nd ed. Benjamin Cummins, Menlo Park, CA.

Kuno, E. 1969. A new method of sequential sampling to obtain a fixed level of precision. Res. Popul. Ecol. 16:281-288.

Kuno, E. 1991. Sampling and analysis of insect populations. Ann. Rev. Entomol. 36:285-304

Kuno, T., and T. Sugino. 1958. On the estimation of the density of rice stems infested by the rice stem borer. J. Pn, J. Appl. Ent. Zool. 2:184-188. (in Japanese, English summary)

Hurlbert, S.H.1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 52:577-580.

Legg, D.E., and K.V. Yearcan. 1985. Methods for random sampling insect population. J. Econ. Entomol. 78:1003-1006.

Lloyd, M. 1967. Mean crowding. J. Anim. Ecol. 36:1-30

Magurran, A.E. 1988. Ecological diversity and its measurements. Princeton Univ. Press, Princeton, NJ.

Marshall, S.A. 1992. Biodiversity and insect collections. Can. Biodiversity 2:16-22.

Martin, J.E.H. 1977. Collecting, preparing and preserving insects, mites, and spiders. The Insects and Arachnids of Canada, Part 1. Publ. 1643, Res. Br., Canada Dep. Agric., Ottawa, ON.

May, R.M. 1986. The search for patterns in the balance of nature: Advances and retreats. Ecology 67:1115-1126.

May, R.M. 1992. How many species inhabit the earth? Scientific American 267:42-48.

Milne, W.M. 1993. Detachable bags for multiple sweep net samples. Antenna, Bull. R. Ent. Soc. 17:14-15.

Morris, R.F. 1955. The development of sampling techniques for forest insect defoliators, with particular reference to the spruce budworm. Can. J. Zool. 33:225-294.

Muirhead-Thompson, R.C. 1991. Trap responses of flying insects: The influence of trap design on capture efficiency. Academic Press.

Nachman, G. 1984. Estimates of mean population density and spatial distribution of *Tetranchus urticae* (Acarina: Tetranychidae) and *Phytoseiulus persimilis* (Acarina: Phytoseiidae) based upon the proportion of empty sampling units. J. Appl. Ecol. 21:903-913.

Pielou, E.C. 1977. Mathematical Ecology. Wiley. New York, NY. 302 pp.

Platnick, N.I. 1991. Patterns of biodiversity: Tropical vs. temperate. J. Nat. Hist. 25:1083-1088.

Schreuder, H.T., T.G. Gregoire and G.B. Wood. 1993. Sampling methods for multiresource forest inventory. Wiley. New York, NY. 446 pp.

Seber, G.A.F. 1982. The estimation of animal abundance. 2nd ed. Griffin. London. 654 pp.

Scudder, G.G.E. 1993 (in press). Ranking of inventory requirements for B.C., terrestrial and freshwater invertebrates. Min. Environ., Lands, and Parks.

Soulé, M.E. 1991. Conservation:Tactics for a constant crisis. Science 253:744-749.

Southwood, T.R.E. 1978. The components of diversity. In Diversity of insect faunas. Edited by L.A. Mound and N. Waloff. Symposia of the Royal Entomological Society No. 9. pp. 19-40.

Steyskal, G.E. 1981. A bibliography of the Malaise trap. Proc. Entomol. Soc. Wash. 83:225-229.

Taylor, L.R. 1961. Aggregation, variance and the mean. Nature 189:732-753.

Townes, H. 1962. Design for a Malaise trap. Proc. Entomol. Soc. Wash. 64:253-262.

Wald, A. 1947. Sequential analysis. Wiley. New York, NY. 212 pp.

Walker, B.H. 1992. Biodiversity and ecological redundancy. Conserv. Biol. 6:18-23.

White, G.C., and R.E. Bennets. 1996. Analysis of frequency count data using the negative binomial distribution. Ecology 77:2549-2557.

Winchester, N.N. 1992. Community ecology of the insect/arthropod fauna from an old-growth forest, with special emphasis on the canopy fauna. Unpubl. rep. submitted to the Res. Br., B.C. Min. For., Victoria, BC.

Zar, J.H. 1996. Biostatistical Analysis. 3rd ed. Prentice-Hall, London.

Additional References (Sampling Techniques)

Belshaw, R. 1993. Malaise traps and Tachinidae (Diptera): A study of sampling efficiency. The Entomologist 112:49-54.

Chapman, J.A., and J.M. Kinghom. 1955. Window flight traps for insects. Can. Ent. 87:46-47.

Darling, D.C., and L. Packer. 1988. Effectiveness of Malaise traps in collecting Hymenoptera: The influence of trap design, mesh size, and location. Can. Ent. 120:787-796.

Evans, D.A., and J.T. Medler. 1966. Improved method of using yellowpan aphid traps. J. Econ. Ent. 59:1526-1527.

Hardwick, D.F. 1968. A brief review of the principles of light trap design with a description of an efficient trap for collecting noctuid moths. J. Lepid. Soc. 22:65-75.

Hutcheson, J. 1990. Characterization of terrestrial insect communities using quantified Malaise-trapped Coleoptera. Ecol. Ent. 15:143-151.

Ivie, L.L., and M.A. Ivie. 1992. Flight intercepts and Lindgren vs. pitfall traps as quantitative devices for coleopteran biodiversity measurement. Abstract, Entomological Society of America annual meeting, 1992.

Johnson, C.G. 1950. The comparison of suction trap, sticky trap and tow net for quantitative sampling of small airborne insects. Ann. Appl. Biol. 37:268-285.

Juillet, J.A. 1963. A comparison of four types of trap used for capturing flying insects. Can. J. Zool. 41:219-223.

Masner, L., and G.A.P. Gibson. 1979. The separation bag - a new device to aid in collecting insects. Can. Ent. 111:1197-1198.

Masner, L., and H. Goulet. 1983. A new model of flight-interception trap for some hymenopterous insects. Ent. Am. Inst. 20:428-432.

Niemela, J., E. Halme and Y. Haila. 1990. Balancing sampling effort in pitfall trapping of carabid beetles. Entomologica Fennica 1:233-238.

Peck, S.B, and J. Cook. 1992. Use of "car nets" to sample flying micro-Coleoptera. Can. Ent. 124:745-749.

Peck, S.B., and S.E. Davies. 1980. Collecting small beetles with large-area "window" traps. Coleopt. Bull. 34:237-239.

Pedigo, L., and G.D. Buntin (eds.). 1993. Handbook of Sampling Methodology for Arthropods in Agriculture. CRC Press Inc. 616 pp.

Peterson, A. 1959. A Manual of Entomological Techniques. How to Work with Insects. 9th ed. Edward Brothers Inc., Ann Arbor, Mich. 435 pp.

Slinger, G. 1964. A simple aspirator for collecting small arthropods directly into alcohol. Ann. Entomol. Soc. Am. 57:796-798.

Southwood, T.R.F. 1978. Ecological Methods with Particular Reference to the Study of Insect Populations. 2nd. ed. Wiley. New York, NY. 542 pp.

Taylor, L.R., and Palmer, M.P. 1972. Aerial spraying. Pages 189-234 *in* H.F. van Emden, ed. Aphid Technology. Academic Press, London and New York.

van den Berghe, E. 1992. On pitfall trapping invertebrates. Ent. News, 103:149-156. A.

Appendix

Appendix A. Label Preparation for Insect Specimens

J. Huber (Biosystematics Research Centre, Ottawa, Ont.)

Specimens sent in for identification to B.R.C. through the National Identification Service often are poorly labelled. Either the label does not have the basic minimum data, or it is poorly organized or illegible. Code numbers are often the only item present. This is useless to the taxonimist. If the specimens are to be useful enough to be incorporated into a regional or national collection where they can be used for revisionary studies, or kept as voucher specimens they must be labelled properly. If not, a disservice is being done not only to the taxonomist but also to the person submitting the specimen. So please take a moment to write out proper identification labels for specimens submitted.

Identifications of insects that are COMPLETE (i.e. to species), ACCURATE (i.e. correct according to the latest available knowledge of a group), and RELIABLE (i.e. the same name is consistently given to a particular species each time it is submitted for identification) are needed to ensure that research programs using these organisms are not jeopardized because of poor identifications.

Unfortunately, given the incredible diversity and complexity of nature and the sheer number of species to deal with, the taxonomic community is still a long way from being able to provide complete identifications in many groups. There are also many practical problems: insufficient numbers of taxonomists studying important groups, current inability to resolve problems in large or taxonomically difficult groups, lack of good literature and reference collections, etc.

People wanting names for organisms submitted must be reminded that these names are not pulled out of thin air. They are based on existing collections of organisms and continually updated revisionary works (including identification keys). The collections form the basis of the revisionary works and keys. Poor collections (i.e. poor condition of specimens, few specimens, badly labelled specimens) can only result in poor or no revisions and keys. Poor or no revisions and keys mean no way of identifying a submitted specimen to species, or even genus, unless the taxonomist can recognize the species by sight only (certainly not always the case). For many groups of insects, for example, there are no revisions or keys at all. To be able to produce them we need good collections made up of properly labelled specimens in good condition for study. If fewer good revisions are produced as a result of lack of good collections (and, incidentally, lack of full-time professional taxonomists to produce such revisions) then fewer reliable identifications to species level will be possible. So people sending in specimens will get relatively more incomplete of incorrect identifications. This, in turn, will affect the quality of your scientific research. So both taxonomist and submitter, and Canadian science, needlessly lose. Again, please include as complete data as possible with all submitted specimens so taxonomists or other entomologists can use them for their research.

Order of data on labels. COUNTRY (in capitals): lesser political unit, (distance and compass point from nearest community (if necessary)), exact locality (place with post office, etc.), altitude (if useful), latitude & longitude (if necessary), date, collector, habitat, collecting method, host and/or host plant (if relevant).

Punctuation. Colon after country. All other items separated by commas. No punctuation at end of lines or, at least, longest line (since it will tend to be cut). Please cut labels as close as possible to the printing.

Minimum information required. COUNTRY: lesser political unit, exact locality, date, collector, host (if known). PLEASE include genus, species AND author of host.

Biocontrol workers collecting live insects from several localities should give the general area they collected in e.g. SWITZERLAND: Rhine Valley between Basel and Koblenz, and the exact locality for at least one of the collection sites (it may become a type locality).

The above information can be put on two separate labels; one with the date and locality data, the other with habitat, host and collecting method, and any code numbers or letters, e.g., FIDS code, and other cryptic information of use only to the submitter of the specimens. Labels should be printed, if possible, on white, acid-free paper of fairly heavy weight e.g. 20-pound bond. If labels are photocopied then a fused carbon photocopier should be used. Labels should be a maximum of 20 letters (including spaces) per line and five lines long.