Biology 345
Ecology

Field Ecology Workshop Manual 2024

Athabasca University
Faculty of Science and Technology

Course Team

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Materials to bring to the 4-day lab:

Notebook (!), pencils, appropriate clothing, change of clothes, hat and footwear for outdoor activities (hiking boots or rubber boots), (be prepared for rain, mud, high solar radiation, mosquitoes and other biting insects), laptop, textbook (important for students who have not yet completed most parts of the course).

We will work both in the field and in the lab (lab coats are provided).

Be prepared to work outdoors. If you have any physical or medical conditions that require special considerations, the lab instructors must be informed well ahead of time.

Before attending the lab, join the Ecology Landing group: Go to *landing.athabascau.ca* and log in with your AU student ID. In the search field, look for *BIOL 345: ECOLOGY 2024*. Click on the link and *join the group*. All lab results (but not the Lab Report) must be submitted on this site.

Please note that in case of unforeseen events, the lab schedule might be changed on short notice.

Day 1

Our first day will be dedicated to limnology and we will visit various ponds, rivers and streams in the surroundings of the Athabasca University campus. Bring water, change of clothes and footwear, towel, hat, insect repellent, rain gear, sunscreen and footwear that can get wet.
Note: For workshops held at Athabasca University, please arrive by 8:50 AM at the Science Lab (watch for Science Lab signs in the AU Main Building). We will not wait for latecomers. Students can park in any parking space that is not restricted as a loading zone, handicapped parking, etc.

Schedule

Time	Activity
9:00 AM (sharp)	Welcome, introduction, safety briefing, photo release forms, handout of lab manual, student groups to be assigned.
Morning	Athabasca River, Tawatinaw River, Muskeg Creek, various ponds: Aquatic project sample and data collection (data, water sampling, aquatic invertebrate collecting, and aquatic microbe collection).
Noon	Lunch break
Afternoon	Further field sites, collecting and compiling limnological data
5:00 PM (appr.)	End of day

Day 2

On the second day, we will visit two adjacent terrestrial habitats and characterize the invertebrates, vertebrates, and vascular plants in both.

Schedule

Time	Activity
9:00	In Lab: review of Day 1, data entry. If required: Analyze samples and data from Day 1. Prepare for terrestrial producers and invertebrates (gather equipment, gain familiarity with procedures).
Noon	Flexible lunch break
Afternoon	Terrestrial habitats: Invertebrate project, vascular plant project (traps, transect and quadrants). In Lab: identification and weighing of plant samples; identification and weighing of invertebrate samples, review photos from game cameras. Data entry.
5:00 PM	End of Day 2

Day 3

On the third day, we will visit two adjacent terrestrial habitats and characterize the microclimate and soil in both.

Schedule

Time	Activity
Morning	In Lab: preview of day's activities
	In Lab: analyze samples and data collected from Day 2 (finish with invertebrate and vascular plant projects). Data entry.
12:00	Lunch break
Afternoon	Terrestrial habitats: soil sampling and physical factors.
	In Lab: soil testing. Evaluation of Coliscan results from Day 1 (Group 3). Data entry.
5:00 PM	End of Day 3

Day 4

In the morning, we will explore a forest habitat. In the afternoon the groups will discuss the preliminary results of their aquatic research projects. We will wrap up with a review of the 4 days.

Schedule

Time	Activity
9:00	Forest measurement exercise. Data entry.
Noon	Lunch break
Afternoon	Discussion of results
	Lab evaluation by students, Guidelines for Lab reports
5:00 PM	End of Day 4

Day 1: LIMNOLOGY

Introduction

On the first day we will visit various water bodies around Athabasca (Athabasca River, Tawatinaw River, Muskeg Creek, AU Observatory Pond, AU campus pond, etc. We may add other locations if required). Be prepared for some walking to our field sites. Four groups of students will be assigned the following projects:

Group 1. Physical factors
Group 2. Water chemistry
Group 3. Bacteriology of water
Group 4. Aquatic organisms

Required reading

Elements of Ecology Chapter 3, Chapter 21 sect 8, 10, 11, Chapter 24 (excluding marine environment)

Additional resources

Mitchell, P., and E. E. Prepas. (Eds.) 1990. Atlas of Alberta lakes. Edmonton, Alberta: University of Alberta Press

Background

Dissolved oxygen (DO)

Most macroscopic aquatic organisms are aerobic and rely on the oxygen dissolved in water to respire. Oxygen diffuses from the atmosphere into surface water at a rate dependent on the solubility of oxygen in water and the difference in oxygen concentration between the surface water and the atmosphere. The solubility of oxygen into water is dependent on temperature (oxygen is more able to diffuse into colder water). Oxygen can also be introduced to a lake through photosynthesizing plants, cyanobacteria and algae. Oxygen is consumed by the respiration of living organisms (fish, plants, algae, micro and macroinvertebrates) and by decomposition (bacteria, fungi) of organic materials in the lake sediments. In stratified lakes, the oxygen that diffuses from the atmosphere may not reach the hypolimnion resulting in anaerobic conditions.
The Environmental Quality Guidelines for Alberta Surface Waters (Alberta

Government, 2014) indicates that to sustain aerobic organisms in the epilimnion, DO should never drop below 5 mg/L and should not drop below 6.5 mg/L over more than seven days. The guidelines also indicate that the concentration of DO should be higher (above 9.5 mg/L) when the early stages of life (e.g. fish larvae) are developing. In lotic water bodies oxygen (and CO_2) dissolve easier, compared to lentic water bodies.

pH

pH is a measure of the acidity or alkalinity of water, measured by the concentration of hydrogen ions. pH ranges from 0 to 14 and is the negative logarithm of the hydrogen ion concentration. The Environmental Quality Guidelines for Alberta Surface Waters suggest that the pH of 6.5 to 9 is desirable in freshwater. pH influences the solubility of nutrients such as carbon, nitrogen, and phosphorus, as well as the biological availability (the amount that organisms can use them). pH also influences solubility of toxic heavy metals such as aluminum. Read section 3.7 in the textbook for more information on pH and carbon dioxide–carbonic acid–bicarbonate buffering system.

Benthos and plankton

Zoobenthos and zooplankton are small heterotrophic protists and animals such as insects, crustaceans, molluscs, rotifers and worms that live in water. Zoobenthos are organisms that live in the bottom sediment. Some organisms will spend only part of their lifecycle in the sediment, and others will spend their entire life cycle in the sediment. Zoobenthos can range in size from less than 200 µm (microbenthos) to more than 2 mm (macrobenthos). Zooplankton are free- floating, microscopic (typically) heterotrophic organisms. They feed on phytoplankton, bacterioplankton, other zooplankton, and detritus. They are primary consumers and act as a crucial food source for higher trophic levels including fish. In Alberta lakes, zooplankton include culicids (mosquito larvae), rotifers, copepods, and cladocerans (water fleas). Zooplankton can range from 0.2 µm to more than 10 cm. Phytoplankton are autotrophic photosynthetic organisms that include eukaryotic protists, eubacteria and archaebacteria. Phytoplankton rely on light and nutrient availability and are important primary producers in aquatic ecosystems. In Alberta lakes, algal blooms are often a concern due to the toxins that some groups produce.

Bacterioplankton

Aquatic bacteria are found floating in the water (bacterioplankton), associated with decomposing material in the lake substrate, or in biofilms coating rocks and sand. They can contribute a considerable amount of biomass to a lake system. Bacteria have a wide range of nutritional requirements and ecological roles. Through decomposition, heterotrophic

bacteria play an important role in recycling nutrients from nonliving organic matter (detritus). They free nutrients for use by primary producers and increase the nutritional value of detritus for scavenging organisms (Smith, 2016). Autotrophic bacteria are able to use sunlight and CO2 to synthesize carbohydrates. Cyanobacteria ("blue-green algae") are primary producers that are often prevalent in seasonal blooms. Cyanobacteria are bacteria that are unrelated to algae but share the ability to photosynthesize (RAMP, "Aquatic Organisms: Microorganisms", 2017). In the plankton environment, bacteria are consumed by protists such as flagellates and ciliates, and in the benthos by metazoan animals (rotifers and cladocerans) and amoeba-like protists. Viruses also are estimated to consume between 10% to 30% of bacterial communities every day (Smith, 2016).

Project 1: Physical Factors

Group 1 will measure and record all available physical (abiotic) factors at the various water bodies.

Materials to take outdoors: Secchi Disk and attached rope (for measuring depth), 3 thermometers, 2 GPS units (check batteries), extension pole, camera (cell phone OK) notebooks, pens, pencils, labeled bucket to hold materials, some plastic bags (rain protection), fluxmeter, clipboard.

Checklist of parameters to record in the field:

- GPS location, general description of location
- Description of water body (lotic/lentic)
- Date and time
- Weather
- Temperature at depth x
- Flow speed (if applicable)
- Notes
- Photos of water bodies, surroundings, measurement processes, etc.
- Smell, colour and turbidity (Secchi disk)

Safety considerations

Avoid taking samples from slippery slopes or stones. Test first if measurement and sampling can be done safely. Always work with at least one partner.

Methods

GPS: Switch on the GPS unit and give ample time for stabilization as the instrument picks up various satellites. Results must be presented as decimals (e.g. N 60.5674$^{0;}$ E 35.5677^{0}).

Fluxmeter for the measurement of flow speed in rivers. The operation of the fluxmeter will be explained in the field. Use the maximum extension (length) of the unit. Select sample locations that are free from obstructions. Take notes of the specifics of the stream (bends, depth at sample location, etc). Take a minimum of 2 readings per water body and note the depth of the sonde for each reading. Readings must be recorded in meters/second.

Thermometer: allow for some lag time for the thermometer to display a stable reading. Whenever feasible, take readings at various depths.

Secchi Disk: Lower the Secchi Disk until you can no longer / barely see its

pattern. Record the length of the attached rope in cm. This is a measurement of water turbidity (in cm).

Camera: Document your measurements and the field sites.

Sample notebook record:
Amur River, western China, Jilin Province, 31-05-2000, Time 10:52, N 60.5876^0 E 35.5678^0
Lotic, major river, app. 300 m wide (estimation), heavy rainfall, air temperature 19.8^0 C.
Temperature at surface: 9.1^0 C
Temperature in 10 cm depth: 9.0^0 C
Temperature in 20 cm depth: 8.9^0 C
Temperature in 30 cm depth: 9.0^0 C
Flow speed at surface: 6.5 m/sec
Flow speed at 10 cm: 0.5 m/sec
Flow speed at 20 cm: 0.0 m/sec
Measurement was taken at the south bank of the river (straight flow, no river bend)
Record was taken by Francois Guirre, student at Beijing University.
Instruments: digital Hansen 3.45 thermometer, Fisher Fluxmeter 45.1, GPS: Garmin 550
Photos of the research sites are deposited at http://landing.athabascau.ca

Collection of data

Group 1 will complete and submit copies of Table 1 separately for each water body. In addition, the field sites must be documented with photographs.

Table 1: Physical factors (aquatic)

- Use one sheet per location

Location*	
Date:	
Time:	
Weather, Air temperature	
Notes	

		Site 1	Site 2
	GPS location		
Surface	Temp (°C)		
	Flow speed		
Depth 1	Temp (°C)		
	Flow speed		
Depth 2	Temp (°C)		
	Flow speed		
Depth 3	Temp (°C)		
	Flow speed		

*Athabasca River, Tawatinaw River, Muskeg Creek (Middle Bridge), ARC Pond

Project 2: Water Chemistry

Group 2 will measure and record some water chemistry data in the field. Others will be taken in the lab. Note: the dissolved oxygen content and the dissolved CO_2 content are very sensitive to environmental conditions (temperature, water movement, etc.) and are therefore taken in the field (and subsequently in the lab as a control).

Materials to take outdoors: pH test strips (different types), multi parameter test strips for pH, alkalinity, hardness, etc., dissolved oxygen test kit (1 unit), (colourimetric, CHEMMETS), dissolved CO_2 test kit (1 unit), phosphorus test kit (aquatic, 1 unit), potassium test kit (aquatic, 1 unit; NOTE: the sodium hydroxide in the kit must be made fresh before the lab), notebooks and pencils, labeled bucket to hold materials, 20 disposable plastic pipettes, 5 plastic beakers (appr. 250 ml), 5 empty petri dishes, 15 water sample bottles (clean), 3 bottles of distilled water, 3 marker pens, gloves (10 pairs), small plastic bags for waste, camera (cell phone OK).

Materials to be used in the lab (depending on time available and weather conditions, we may take some of these measurements in the field): pH test strips, multi parameter test strips (pH, alkalinity, hardness, etc.), dissolved oxygen test kit, (colourimetric, CHEMMETS), dissolved CO_2 test kit (1 unit), phosphorus test kit (aquatic, 1 unit), pH-meter (4 units), buffer solutions for calibration, potassium test kit (aquatic, 1 unit), 20 disposable plastic pipettes, 3 bottles of distilled water, 5 plastic beakers (appr. 250 ml), camera (cell phone OK), clipboard.

Parameters to record in the field:

- dissolved oxygen
- dissolved CO_2
- pH (various test strips)
- multi parameter test strips (pH, alkalinity, hardness, etc.)

Three water samples per location will be taken back to the lab for further measurements.

Parameters to record in the lab (or in the field, depending on available time and weather conditions):

- dissolved oxygen (repeat measurement for comparison)
- dissolved CO_2 (repeat measurement for comparison)
- potassium content
- phosphorus content
- pH using a pH-meter
- pH using various test strips (compare with pH-meter results)

Safety considerations

Field: Avoid taking samples from slippery slopes or stones. Test first if measurement and sampling can be done safely. Use gloves. Always work with at least one partner. Lab: Read MSDS and individual safety precautions for the tests.

Methods

Water Sampling

Use a collection bottle to take a water sample from the surface of the water body. Whenever feasible, use the extension pole. Use care to not create any turbulence, especially in lentic, sediment rich waters.

Water Testing in the field

Dissolved Oxygen O_2 Test Kit (Indigo Carmine Colourimetric Method)

Contents: Sample cup, 25 ml, plastic, ampoules of indigo carmine, Oxygen Comparator with several blue coloured vials, 1-12 ppm.

1. Fill the sample cup to the 25 ml mark with your water sample.
2. Place an ampoule (with yellow liquid) tip down in the sample cup. Snap the tip by pressing the ampoule against the side of the cup. The ampoule will fill, leaving a small bubble (air-space) to facilitate mixing.
3. Mix the contents of the ampoule by inverting it several times, allowing the bubble to travel from end to end each time. Then wipe all liquid from the exterior of the ampoule. Wait 2 minutes for colour development.
4. Hold the comparator in a horizontal position while standing directly beneath a bright light source (try to avoid reflective interference). Place the ampoule between the colour standards moving it from left to right along the comparator until the best colour match is found. If the colours do not match, a concentration estimate can be made (range).
5. Dispose of excess water sample in a sink. Dispose of broken tip of ampule (if not already emptied into a sink) and ampule in a “sharps” container. Return the chemicals and equipment to the container.
6. Repeat the measurement of dissolved oxygen with a water sample taken to the lab.

Carbon Dioxide (CO_2) Test Kit (LaMotte)

Contents: 20 mL glass test tube with cap, Phenolphthalein indicator 1%, Reagent B, Titrator (syringe), 0-50 divisions

1. Fill test tube to 20 ml mark with sample water.

2. NOTE: For best results test on freshly obtained sample, avoid splashing or prolonged contact with air.
3. Add 2 drops of phenolphthalein indicator. If solution remains colourless, proceed to step
4. If the solution turns red, no free Carbon Dioxide is present.
5. Fill titrator with Reagent B. Insert titrator into center hole of test tube cap.
6. While gently swirling the test tube, add Reagent B one drop at a time, until a faint pink colour is produced and persists for 30 seconds. Read test result where plunger tip meets titrator scale. Record as ppm carbon dioxide.
7. Rinse test tube and titrator with distilled water. Return the chemicals and equipment to the container.
8. Repeat the measurement of dissolved carbon dioxide with a water sample taken to the lab.

Water Testing in the lab (or field, if feasible)

Phosphate CHEMets® Kit

Contents: 25 mL sample cup, activator, ampoules, low and high range comparators.

1. Fill the sample cup to the 25 mL mark with the sample to be tested.
2. Add 2 drops of A-8500 Activator Solution. Cap the sample cup and shake it to mix the contents well.
3. Place the CHEMets® ampoule, tip first, into the sample cup. Snap the tip. The ampoule will fill leaving a bubble for mixing.
4. To mix the ampoule, invert it several times, allowing the bubble to travel from end to end.
5. Dry the ampoule and wait 2 minutes for colour development.
6. Obtain a test result using the appropriate comparator.
7. Low Range Comparator: Place the ampoule, flat end first, into the comparator. Hold the comparator up toward a source of light and view from the bottom. Rotate the comparator until the best colour match is found.
8. High Range Comparator: Place the ampoule between the colour standards until the best colour match is found.

Potassium (K) Test Kit (Lamotte)

Contents: Sodium Hydroxide 6% (must be replaced before the lab), Tetraphenyl-Boron powder, Spoon, Potassium double tube. Brush.

1. Fill sample water into the round tube up to lower line.
2. Add distilled water to the upper line.
3. Add two drops sodium hydroxide (corrosive, use gloves). Cap and mix.
4. Add one measure of Tetraphenylboron powder, using the 50 mg spoon.

5. Cap and shake vigorously for 30 seconds. If potassium is present, a white precipitate will form.
6. Wait for 5 minutes.
7. Shake the tube again, remove cap and insert the square tube with the collar. The square tube will slide down through the collar and fill with liquid.
8. Looking from above, slide the square tube down into the solution until the black dot is no longer visible.
9. Read the scale as ppm K (parts per million potassium).
10. Clean test tubes thoroughly after the experiment.

pH

The pH value is measured with an electrode connected to the instrument. Ensure that the basal part of the electrode is completely immersed in the liquid to be measured. Before and after each measurement, the electrode must be rinsed with distilled water. If you are not using the electrodes for more than a few minutes, ensure that they are immersed in liquid.

Before you take any measurements with the pH-meter, the instrument must be calibrated (standardized) with various buffer solutions. A calibration with various buffers should be done at least once every day.

When you take a measurement, wait for the “Stable” indicator before taking a reading.

Sample notebook record for water chemistry:

14 August 2011, 10:00, Nile River landing
pH field measurement, 10:04 (simple test strip): pH 7
pH field measurement, 10:14 (multi parameter test strip): pH 7.5
pH lab measurement, 14:51 (simple test strip): pH 7
pH lab measurement, 14:55 (multi parameter test strip): pH 7.5
pH lab measurement, pH-meter, 15:32 pH 6.9
dissolved oxygen field measurement, 10:05 (colourimetric): 7 ppm
dissolved oxygen lab measurement, 14:05 (colourimetric): 6 ppm
dissolved CO_2 field measurement, 10:10 (titration): 7 ppm
dissolved CO_2 lab measurement, 14:05 (titration): 6 ppm
potassium (K) lab measurement, 15:10 (titration): 7 ppm
phosphorus (PO_4) lab measurement, 14:05 (colourimetric): 6 ppm

Note: lab measurements were taken with water samples from the field (not freshwater samples)
Measurements taken by Claire Musavene, student at Cairo University

Collection of data

Group 2 will complete and submit copies of Table 2 separately for each water body.

Table 2: Water Chemistry

- Use one sheet per location

Location*	
Date:	
Time:	
Weather, Air temperature	
Notes	

	Field Recordings	Lab Recordings
Time		
Dissolved O_2		
Dissolved CO_2		
pH method 1		
pH method 2		
pH method 3		
pH method 4		
Hardness		
Alkalinity		
phosphate		
potassium		

*Athabasca River, Tawatinaw River, Muskeg Creek (Middle Bridge), ARC Pond

Describe any differences for pH measurements using different methods (various test strips and pH-meter).

Describe any differences for dissolved O_2 and CO_2 measurements between lab and field.

Project 3: Bacteriology

Group 3 will take two water samples per location. After completion, Group 3 will assist Group 4 in the field.

Activities in the field:

- Collect two water samples per location. Keep on ice.

Lab activities:

- use the water samples to run the Coliscan test (1 or 2 tests per location)

Materials to take outdoors: 10 sterile water collection bottles, 3 marker pens, cooler box with ice, camera (cell phone OK).

Materials to be used in the lab: Coliscan test kit. Disposable 1 mL plastic pipets (1 bag), 37 ^{0}C incubator.

Safety considerations

Field: Avoid taking samples from slippery slopes or stones. Test first if measurement and sampling can be done safely. Always work with at least one partner.
Lab: After analyzing the results and taking high quality photos, the petri dishes must be disposed of in a red autoclave bag for subsequent sterilization.

Methods

Water Sampling

Use a collection bottle to take a water sample from the surface of the water body. When feasible, use an extension pole. Use care to not create any turbulence, especially in lentic, sediment rich waters. After filling your sample bottles, keep them on ice, for later processing in the lab.

Coliscan® Easygel®water testing for *E. coli* and total coliforms.

Coliform bacteria are lactose-fermenting, gas-producing, Gram-negative rods in the family Enterobacteriaceae. They are often found in soil and water. Fecal coliforms are found in human and animal digestive tracts and when found in water bodies can indicate fecal contamination. *E. coli* is a dominant component of the intestinal microbiome and is often used as an indicator of

fecal contamination from waste treatment, natural animal waste, or agricultural activities.
Use each of your samples to prepare a Coliscan Easygel plate. The solidified plates will be incubated at 37˚C.

Coliscan® Easygel® Instructions (slightly modified from the provided instructions)

The Coliscan® Easygel® medium is a patented formulation for water testing. It contains a sugar linked to a dye which, when acted on by the enzyme β-galactosidase (produced by coliforms including *E. coli*), turns the colony a pink colour. Similarly, there is a second sugar linked to a different dye which produces a blue-green colour when acted on by the enzyme β-glucuronidase. Because *E. coli* produces both β-galactosidase and β- glucuronidase, *E.coli* colonies grow with a purple colour (pink + blue). The combination of these two dyes makes possible the unique ability to use one test to differentiate and quantify coliforms and *E. coli*. (Because *E. coli* is a member of the coliform group, add the number of purple colonies to the number of pink colonies when counting total coliforms.)

Instructions

1. Collect your water samples (2 replicates per location) in a sterile container and store on ice. Transport the water back to the lab.
2. Label the petri dishes with the appropriate sample information. A permanent marker or wax pencil will work.
3. Sterilely transfer 1 mL water from the sample containers into the bottles of Coliscan® Easygel®. Swirl the bottles to distribute the inoculum and then pour the medium/inoculum mixtures into the correctly labeled petri dishes. Place the lids back on to the petri dishes. Gently swirl the poured dish until the entire dish is covered with liquid (but be careful not to splash over the side or on the lid).
4. The dishes may be placed right-side-up directly into a level incubator or warm level spot in the room while still
   liquid. Solidification will occur in approximately 45 minutes.
5. Incubate at 35^0 C for 24 hours, or at room temperature (20^0 C) for 48 hours.
6. Inspect the dishes.
   a. Count all the purple colonies on the Coliscan dish (disregard any light blue, blue-green or white colonies), and report the results in terms of *E. coli* or Fecal Coliform per mL of water. Fecal coliforms are typically reported per 100 mL, therefore you multiply the number of counts on your plate with 100 in order to obtain Fecal coliforms/100 mL. (therefore 2 purple colonies equals 200 fecal coliforms/100 mL).
   b. Count all the pink **plus** the purple colonies on the Coliscan dish (disregard any light blue, blue-green or white colonies) and report the

results in terms of coliforms per mL of water. Multiply by 100 to obtain total coliforms/100 mL. Record and describe any colonies that are neither pink nor purple separately.

Sample notebook record for Coliscan:

1 July 2019, 10:05, Murray River (Physical factors and more details to be obtained from Group 1)
Water was collected in 2 sample bottles and transported back to the lab. The Coliscan test was carried out at 13:03 with collected water samples from the field (not freshwater samples).
Reading of results, Replicate 1: 4 July 2019, 06:20
Pink colonies: 30
Purple colonies: 17
Unidentified colonies: 3 small gray colonies and 2 white colonies, < 1mm
Data recorded by Matilda Beguirre, student at the University of New Delhi

Note: All records above must be accompanied by good quality photos of the plates confirming your stated results.

Collection of data

Group 3 will complete and submit a copy of Table 3. Results will become available on Day 2 or Day 3. In addition, all results must be documented photographically.

Table 3: Bacteriology				
Date: Notes:	Replicate 1: # Purple colonies / # Pink colonies Additional colonies (if any)	Replicate 1: Fecal coliforms/100mL Total coliforms/100mL	Replicate 2: # Purple colonies / # Pink colonies Additional colonies (if any)	Replicate 2: Fecal coliforms/100mL Total coliforms/100mL
Muskeg Creek, Middle Bridge Time:				
Athabasca River, Landing Time:				
Tawatinaw River Time:				
AU ARC Pond Time:				
AU Observatory Pond Time:				
Location 6: Time:				
Location 7: Time:				
Location 8: Time:				
Location Peace River: Time: 10:06	Example: 4/7 Two unidentified gray colonies were also observed	400/1100	Example: 2/8 Two large, white unidentified colonies were also observed	200/1000

Project 4: Aquatic organisms

Group 4 will collect invertebrates, aquatic plants and protists from water and sediment. Vertebrates will be recorded but not collected.

Materials to take outdoors: 10 clean water collection bottles (wide mouth, large size), 1 small bucket for sediments, 3 aquarium nets, 3 strainers of various sizes, five forceps (large and small sizes), disposable plastic pipets (1 bag), 2 trowels to collect sediments, 2 large plastic funnels, 10 white plastic trays with various sizes, ziploc bags (1 box, medium size, 1 box large size), 2 clipboards, 3 marker pens, camera (cell phone OK), bags for carrying heavy water samples (ideally back packs).

Materials to be used in the lab: 5 dissection microscopes, 1 compound microscope, 5 plastic strainers of various sizes, 10 white plastic trays with various sizes, (same as from field activities), set of sieves with assorted mesh sizes, 30 empty petri plates, 1 regular balance, disposable plastic pipets (1 bag).

Activities in the field

Check out each sample site by taking preliminary observations on the richness of flora and fauna. Evaluate collected samples in the trays.
Field results must be amply documented with photos.

At the main site (Muskeg Creek):

Collect both water (plankton) and sediment samples for lab analysis, as well as individual invertebrates or plants.

- collect water sediment and water samples for immediate preliminary observation in the field (use white trays for examination in the field); take sediment in a bucket back to the lab for further observations
- collect plants and invertebrates in larger bottles or large ziploc bags
- take photographs in the field and record all aquatic animals and plants that are not taken to the lab

Lab activities

- use identification keys and microscopes to identify the collected organisms as accurately as possible
- use the stacked sieves for filtering your sediment samples and record your organisms qualitatively (see below)

Safety considerations

Field: Avoid taking samples from slippery slopes or stones. Test first if measurement and sampling can be done safely. Always work with at least one partner.

Methods

Sediment samples are separated in the lab through a set of sieves with assorted mesh sizes.

1. Pass the entire sample (do not sub-sample) through a nested column of sieves ranging in opening sizes of 4 mm to 425 µm. The larger opening sizes must be towards the top.

2. Collect the organisms caught in the sieve into white trays for sorting. Use Petri plates to sort the organisms into subgroups.

3. Enter the results for Zoobenthos in Table 4.

4. Enter the results for Plankton in Table 5. These are the freely floating organisms in your water samples (not zoobenthos).

5. Enter any notes about aquatic plants in Table 6.

Note: Compound and dissection microscopes will be necessary for most identifications. Consult your lab instructors if you need help with the microscopes.

Identify the collected organisms as precisely as possible using books and online resources provided in the lab manual.

Table 4: Zoobenthos		
Location, Date and Time:		
Phylum	Class/Order	Count
Porifera	Sponges	
Cnidaria	Hydrozoa	
Plathyhelminthes	Flatworms	
Nematoda	Roundworms	
Annelida	Olligochaeta	
Annelida	Hirudinea (leeches)	
Mollusca	Gastropoda (snails & limpets)	
Mollusca	Bivalvia (clams)	
Arthropoda	Hydrachnidia (aquatic mites)	
Arthropoda	Cladocera (water fleas)	
Arthropoda	Ostracoda (seed shrimp)	
Arthropoda	Copepoda (copepods)	
Arthropoda	Amphipoda (scuds)	
Arthropoda	Isopoda (sow bugs)	
Arthropoda	Decapoda (crayfish)	
Arthropoda	Ephemeroptera (mayflies)	
Arthropoda	Odonata (dragonflies and damselflies)	
Arthropoda	Plecoptera (stoneflies)	
Arthropoda	Hemiptera (true bugs)	
Arthropoda	Megaloptera (fishflies, alderflies)	
Arthropoda	Lepidoptera (aquatic moths)	
Arthropoda	Trichoptera (caddisflies)	
Arthropoda	Coleoptera (beetle adult)	
Arthropoda	Coleoptera (beetle larva)	
Arthropoda	Diptera (flies and mosquitoes)	
	Other animal groups	
	Additional observations and observations from other sites	

Table 5: Plankton organisms		
Group	Total count	Concentration (Organisms / mL): for highly frequent groups
Culicids		
Copepods		
Cladocerans		
Rotifers		
Ostracods		
Others		
Additional Notes:		

Table 6: Aquatic plants	
Mosses	Notes on aquatic plants:
Monocots	
Dicots	
Additional Notes:	

Day 2: TERRESTRIAL PRODUCERS AND CONSUMERS

Introduction

Over 91% of the total area of Canada is terrestrial and roughly 9% of the world's forests are found in Canada. In these exercises we will be surveying the terrestrial plant community and invertebrate community in two adjacent habitats.

Project 5: Terrestrial Producers

Group 5 will use transect sampling to explore a transition zone from a natural forest environment to a human-created meadow.

Materials to take outdoors: Small metal quadrats, large plastic quadrats, grass sheers, pruning sheers, white plastic or enamel pans, measuring tape, 100 m and 30 m chain, data sheets (multiple copies from lab manual), scrap paper (several sheets), plastic bags for specimen collection, rulers to measure tree diameters, 10 marker pens, several pens and pencils.

Materials to be used in the lab: 5 balances, dissection microscopes, trays for plants, identification keys.

Methods

A 100 m transect (with a surveyor "chain") will be set up between the forest and meadow. The large quadrats are positioned to the right of the "chain" in 10 m intervals and all 0.1 m^2 quadrats are positioned equally within the 1 m^2 quadrats.

Fig. 1: Small rectangle within large quadrat.

Run the chain from the meadow into the forest. Start in the meadow and position the chain so that approximately 50 m of the chain is in the meadow and 50 m is in the forest.

At the 0 m mark both a 0.1 m^2 and a 1 m^2 quadrat will be placed to the right of the meter marking on the chain. The 0.1 m^2 quadrat is nested within the 1 m^2 quadrat.

In each 0.1 m^2 quadrat at ground level clip off live material of all plants less than 1 m tall and record numbers of each within the quadrat. Save each aboveground plant species in separate plastic bags for later weighing. If you do not know the species then choose some identifier (e.g. grass "A," herb "B") and we will standardize all the plant names in

the lab. Record the quadrat number and plant species on a slip of paper and put the paper in the plastic bag with the appropriate plants.

In each 1 m^2 quadrat record the diameter and height of woody plants greater than 1.0 m tall.

Repeat steps 2 through 4 for the remaining 10 intervals on the chain.

In the lab

- Identify each species of herbaceous plant.
- Use a pan balance to weigh all individuals of each species per quadrat.

Data Recording

Table 7. Understory plants (for plants less than 1 m high in a 0.1 m^2 quadrat)
** you will need 1 copy per quadrat or 11 in total

Location on transect (m)	Plant species	Number of individuals in quadrat	Wet Mass (g)	Wet Mass per m^2 (multiply by 10)

Table 8. Woody plants greater than 1 m high (1 m^2 quadrat)

Location (m)	Plant species	Diameter estimate (cm)	Height estimate (m)	Volume (cm^3)	Biomass (g)

Note. Biomass of woody plants over 1 m tall will be estimated by measuring the basal radius (r = 1/2 diameter), estimating the height (h in centimeters) of the plant, using the formula for the volume a cone $V = 1/3\ \pi r^2 h$, and using 1 cm^3 = 1 g for the biomass of the tall woody plants.

Table 9: Quadrats in an Ecotone between Two Terrestrial Habitats (meadow and forest).

General grouping of plants	Transect station (m from start)	0		10		20		30		40		50	
	Plant Species/ Group	Absolute Density (number/m^2)	Mass (g/m^2)	Absolute Density (number/m^2)	Mass (g/m^2)	Absolute Density (number/m^2)	Mass (g/m^2)	Absolute Density (number/m^2)	Mass (g/m^2)	Absolute Density (number/m^2)	Mass (g/m^2)	Absolute Density (number/m^2)	Mass (g/m^2)
Monocots 1													
2													
3													
4													
5													
Herbaceous dicots 1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
Woody dicots 1													
2													
3													
4													
Miscellaneous													
	Totals												

General grouping of plants	Transect station (m from start)	60		70		80		90		100			
	Plant Species/ Group	Absolute Density (number/m^2)	Mass (g/m^2)	Absolute Density (number/m^2)	Mass (g/m^2)	Absolute Density (number/m^2)	Mass (g/m^2)	Absolute Density (number/m^2)	Mass (g/m^2)	Absolute Density (number/m^2)	Mass (g/m^2)		
Monocots 1													
2													
3													
4													
5													
Herbaceous dicots 1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
Woody dicots 1													
2													
3													
4													
Miscellaneous													
	Totals												

Measuring the Diversity of the plot (field and forest)

For measuring the diversity of biomes, ecosystems, and habitats ecologists use a variety if mathematical indices. The most commonly used ones are Simpson's diversity index and the Shannon diversity index.

For our site we will use Simpson's index (note that there are at least three versions of this index, we will use the more intuitive inverse index):

$1/D = N\ (N - 1)/\sum n_i\ (n_i - 1)$

1/D = Diversity of the habitat
N = Total number of individuals in the community
n_i = total number of individuals of species i

After populating Table 10, calculate Simpson's inverse index for our habitat.

Table 10. Relative abundance of plant species. For plant species counted within the 0.1 m^2 quadrant, multiply the number of individuals by 10 to compare to the 1 m^2 quadrant)

Plant species	Number of individuals (n_i)	Relative Abundance (percentage of total individuals)	Rank Abundance
Totals	N=	100%	
Simpson's inverse index 1/D =			

Project 6. Terrestrial invertebrates and Berlese funnels

Invertebrates are a very diverse group of animals. We will compare invertebrate and vertebrate communities in adjacent forest and meadow habitats using traps, game camera recordings and nets.

Materials used in the field: Mechanical aspirators, clear plastic vials for holding insects, beating nets, butterfly nets, beating trays, insect killing jars, ethyl acetate or chloroform for killing jars, collection bottles and sieves for pit-fall traps and ramp traps, light trap, battery, buckets for carrying, 8 pails for pit traps, 4 pails for ramp traps

Trap killing mixture: equal amounts of 50% propylene glycol and 75% ethanol, added by a few drops of detergent.

Materials used in the lab: Dissecting microscopes, Dissecting kits, Petri dishes, Pan balances, Insects of Alberta display box Appendices for invertebrate identification, Library resources for invertebrate identification
Berlese funnels attached to a lamp.

Methods

Activities in the field

- Collect the contents of pit-fall traps (Figures 2 and 3). Pit-fall traps are plastic containers filled with a propylene glycol mixture. The container is placed in a small hole such that the top of the container is flush with the ground. Small ground-dwelling animals will fall into the trap where they are preserved by propylene glycol. The pit-fall traps were set up two weeks before the lab. Carefully remove the plywood cover. Place a funnel with sieve over the propylene glycol waste container. Lift out the trap and pour the contents through the sieve. Place the insects into a collection jar. Label.
- Collect the contents of ramp traps. Ramp traps are similar to pit-fall traps except that the top of the trap is elevated, and small animals enter the trap through clear plastic ramps on either side of the trap. Ramp traps are most effective in rocky and hard ground where it is not possible to dig a whole.
- The instructors will demonstrate the use of beating nets, butterfly nets, beating trays and aspirators. Use each technique of collecting insects for the same amount of time in the forest and the meadow habitats. For example, if you use the butterfly net for 20 minutes in the meadow then use the butterfly net for a second 20-minute period in the forest. Count the number of each order of insects collected using these methods. If live identification is possible then release the

insects. A killing jar may be used to kill insects that must be identified in the lab.

- The instructors have previously set up a light trap in each of the forest and meadow habitats. Light traps are used to catch night-time flying insects that are attracted to UV light (Figure 4). These traps consist of a light source powered by a car battery. The insects are attracted to the light (simulating the moon) and collide with clear Plexiglas panes radiating from the light source. The stunned insects drop into a bucket that contains a preservative (ethanol). The traps will be in place for one night at each site. Collect the content of the traps. The ethanol in the trap must be collected for disposal.

Activities in the lab

- Empty the contents from traps into plastic trays. For each trap type count the number of invertebrates in each order. Use Petri plates (used) to help separate the insects into groups.
- Use pan balances to weigh the contents of each group.
- Evaluate separately the results from the Berlese funnels which have been prepared in advance from various soils.

Figure 2. Uncovered pit-fall trap. Photo courtesy of C. Allen.

Figure 3. Pit-fall trap with plywood cover. Photo courtesy of C. Allen.

Figure 4. Light trap in operation. Battery enclosed in plastic bin. Photo courtesy of C. Allen

Animal Group	Common names	Forest						Meadow					
		Pit traps		Ramp traps		Light trap		Pit traps		Ramp traps		Light trap	
		No.	Mass (g)	No.	Mass (g)	No.	Mass (g)	No.	Mass (g)	No.	Mass (g)	No.	Mass (g)
Annelida, Oligocheata	earth worms												
Mollusca, Gastropoda	snails, slugs												
Arachnida, Acari	mites and ticks												
Arachnida, Araneae	spiders												
Arachnida, Opiliones	harvestmen/ daddylonglegs												
Chilopoda	centipedes												
Collembola	springtails												
Insecta, Orthoptera	grasshoppers, crickets												
Insecta, Hemiptera	bugs: “half wings”												
Insecta, Homoptera	aphids, plant hoppers												
Insecta, Coleoptera	beetles												
Insecta, Trichoptera	caddisflies												
Insecta, Lepidoptera	butterflies and moths												
Insecta, Diptera	flies, mosquitoes												
Insecta, Hymenoptera	ants, wasps, bees												
Totals													

Table 11. Invertebrates collected using traps in two terrestrial habitats (meadow and forest).

Dates of pit trap collections: Numbers of pit traps per habitat:
Trap days (number of traps x number of days):

Dates of ramp trap collections: Number of ramp traps per habitat:
Trap days (number of traps x number of days):

Dates of light trap collections: Numbers of light traps per habitat:
Trap days (number of traps x number of days):

Table 12. Invertebrates collected using hand nets in two terrestrial habitats (meadow and forest).
Time spent beat netting: Time spent butterfly netting: Time spent with beating tray:

Animal Group	Common names	Forest			Meadow		
		Beat net	Butterfly net	Beating tray	Beat net	Butterfly net	Beating tray
		No.	No.	No.	No.	No.	No.
Annelida, Oligocheata	earth worms						
Mollusca, Gastropoda	snails, slugs						
Arachnida, Acari	mites and ticks						
Arachnida, Araneae	spiders						
Arachnida, Opiliones	harvestmen/ daddylonglegs						
Chilopoda	centipedes						
Collembola	springtails						
Insecta, Orthoptera	grasshoppers, crickets						
Insecta, Hemiptera	bugs: “half wings”						
Insecta, Homoptera	aphids, plant hoppers						
Insecta, Coleoptera	beetles						
Insecta, Trichoptera	caddisflies						
Insecta, Lepidoptera	butterflies and moths						
Insecta, Diptera	flies, mosquitoes						
Insecta, Hymenoptera	ants, wasps, bees						
Totals							

Day 3: ABIOTIC FACTORS (TERRESTRIAL)

Introduction

In the first part of this exercise, we will compare the microclimates of two adjacent terrestrial habitats. We will also use a soil auger to collect soil samples and take temperatures of the soil at various depths and determine various soil nutrient levels.

Group 7 will measure and record climate and temperature data in the field. Soil cores will be taken for later analysis.

Materials to be used outdoors: 2 Stevenson screens, 2 rain gauges, 2 HOBO loggers, Garmin GPS, Max/min thermometer, alcohol/mercury thermometer, soil thermometer, soil auger with extensions, spatula, 3 thermocouples on soil probe, bags for soil samples, anemometer, light meter, marker pens, infrared thermometer, camera (cell phone OK).

Materials to be used in the lab: pH-meter (use only the units designated for soil suspensions), pH test strips (different types), 20 beakers (250 mL), 20 beakers (400 mL), 20 small strainers, 10 beakers (plastic or glass, 100 mL), 10 empty petri dishes, distilled water, stock solutions of KCl and $CaCl_2$.

Methods

Activities in the field

The lab instructors will demonstrate the use of devices.

Instantaneous meteorological measurements in each habitat type:

- Use a GPS device to determine the location and elevation of the habitats. Try a few different units to see if they are consistent.
- Measure the air temperature using an alcohol thermometer.
- Measure the relative humidity using a hygrometer.
- Use an infrared thermometer to measure the temperature of a plant surface in the sun and the shade.
- Measure the light intensity using a light meter.
- Measure the wind velocity at ground level and 1 m above the surface using an anemometer.
- Use a soil auger to drill 1.2 m into the soil substrate. Record the depth of each soil horizon (O, A, B). Take photos.
- Use a pre-prepared stick with thermocouples attached at 0 cm (surface), 20 cm, 40 cm, 60 cm, 80 cm, 100 cm and 120 cm to measure

the soil temperature.

Prolonged meteorological measurements in each habitat type:

- Open the Stevenson's screen
- Measure the current temperature using a maximum/minimum thermometer.
- Record the maximum and minimum temperatures experienced by the thermometer since last reset.
- Collect the Hobo Logger with thermocouple and bring to the lab for data harvest.
- Use rain gauge to measure the amount of precipitation.

Soil sampling

- Use a soil auger to view the soil profile for the two sites. Record as described above (notes and photographs). Collect soil from the A (topsoil), and B (subsoil) horizons for pH measurements. Place the samples in labeled plastic bags.

Activities in the lab

Prepare 3 soil suspensions by mixing equal amounts (e.g. 60 g soil in 60 mL solution) of soil samples with

- distilled water
- $CaCl_2$ stock solution
- KCl stock solution

Immerse for at least 30 minutes. This will work best for the B horizon. You may have to strain the soil suspension repeatedly in order to obtain a soil suspension that can be used for the pH measurement. Measure the pH both with a pH-meter and with various pH test strips.

Using the pH-meter: Use only the units assigned for soil suspensions. The pH value is measured with an electrode connected to the instrument. Ensure that the basal part of the electrode is completely immersed in the liquid to be measured. Before and after each measurement, the electrode must be rinsed with distilled water. If you are not using the electrodes for more than a few minutes, ensure that they are immersed in liquid.

Before you take any measurements with the pH-meter, the instrument must be calibrated (standardized) with various buffer solutions. A calibration with various buffers should be done at least once every day.

When you take a measurement, wait for the "Stable" indicator before taking a reading. Record your results for both sites.

Table 13: Abiotic factors Forest/Meadow Date and Time:		
	Forest	Meadow
Location (GPS) / elevation		
Temperature: current/max/min		
Temperature Air – 1 m		
Temperature Air – soil interface		
Temperature inside substrate: temperature/depth (include all depths provided)		
Temperature Plant surface in sun		
Temperature Plant surface in shade		
Relative humidity		
Precipitation in mm (absolute) / mm per month		
Light intensity 1 m above surface		
Wind velocity 1 m		
Wind velocity ground		
Notes on Hobo logger results (e.g. maximum/minimum for both temperature and humidity): In addition to submitting this table, the Hobo logger graphs must be uploaded to the AU Landing.		

Table 14: soil pH Date and Time:		
	Forest	Meadow
pH in distilled water (pH-meter)		
pH in KCl (pH-meter)		
pH in $CaCl_2$ (pH-meter)		
pH test strip reading (indicate type)		
pH test strip reading (indicate type)		
pH test strip reading (indicate type)		
Additional notes: (e.g. soil horizon used)		

Day 4: FOREST MEASUREMENTS

Introduction

The boreal forest covers close to 60% of Canada's land area. The forest stretches from the east to west coast and is mostly above the 50th parallel. The boreal forest benefits Canadians economically, including a widely distributed forestry sector that is crucial to many rural communities across the country. The trees and understory plants filter pollutants from the air and water. The boreal forest creates essential habitat for native plant and animal species, sustaining biological diversity within our country. The boreal forest provides opportunities for recreation, cultural, and spiritual activities.
Disturbances play a large role in the shape of Canada's forests. Natural disturbances have been influencing forest structure since the last glaciation and include fire, insects, disease, drought, and windstorms. These disturbances can renew entire forest landscapes and alter forest composition, structure, and habitat diversity. Humans also disturb the forest ecosystem through harvesting, energy sector activities, road construction, conversion to agriculture, and so on.
Forests are a vital component of the carbon cycle, storing and releasing carbon through growth, decay, disturbance, and renewal.
Forest professionals must be able to measure the condition and state of forest resources in order to make decisions about forest health and management.

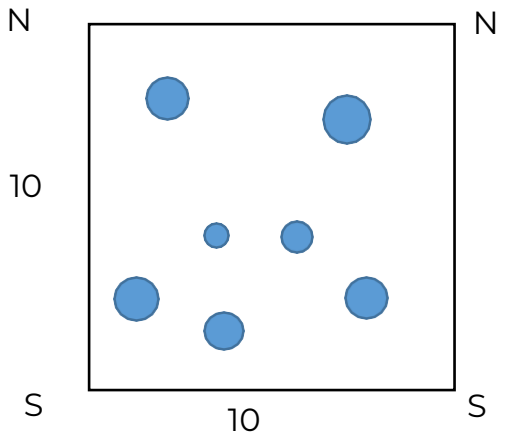
In this exercise we will learn some of the basic techniques of forest measurement.

Materials to take outdoors: 20-meter tape, clinometer, increment borer, DBH tape, compass, flags, flagging tape, core holder, hypsometer, folding meter, Range finder ("Bushnell", for measuring distances).

Materials to be used in the lab: dissection scope

Methods

In a forested area on the AU campus, we will lay down a 10 m by 10 m plot. The sides of the square plot will run north to south and east to west. Use a compass and measuring tape to define the boundaries of the plot and mark them clearly.



Total area = 100 m^2

Use flags to mark the periphery of the plot.

Using flagging tape to mark trees near the border of the plot

For each tree > 5 cm diameter at breast height (DBH) within the plot

- Identify the species.
- Measure the DBH using the DBH tape. Wrap the DBH tape around the tree at 1.4 m from the base of the tree. Measure the diameter in centimeters. If no DBH tape is available, then measure the circumference at 1.4 m and divide by π.
- Determine the height using a 20 m measuring tape (or a "range finder" and a hypsometer. An instructor will demonstrate how to use the hypsometer.
- For one tree of each species within the plot: Determine the age using an increment borer. An instructor will demonstrate how to use an increment borer. Data Collection

Tree measurements

Table 15. Calculate the basal area and volume of each tree.

Tree #	Tree species	DBH (m)	Basal Area (m^2)	Height (m)	Volume (m^3)

Basal area (BA) per tree is calculated as π x $(DBH/2)^2$. Volume measurements are taken from the single tree volume tables (Appendix) Data Analysis

Density

Table 16. For each tree species calculate the absolute density per hectare. A hectare is defined as 100 m by 100 m or 10000 m^2.

Tree Species	Number of trees per 100 m^2	Absolute density per hectare (move two decimal places)	Relative Density (%)
Totals		Total density =	100%

Note. Relative density of a species is calculated as (absolute density of the species/total density of all species) x 100.

Basal Area

Table 17. For each tree species calculate the total basal area per hectare (m^2/hectare). A hectare is defined as 100 m by 100 m or 10000 m^2.

Tree Species	Basal Area in 100 m^2	Basal Area per hectare (move two decimal places)	Relative Dominance (%)
Totals			100%

Note. Relative dominance of a species is calculated as (basal area of the species/total basal area of all species) x 100.

BIOL 345 Assessment for Field Ecology Workshop

The laboratory component for BIOL 345 is worth 20% of your total grade, and a minimum of 50% on the lab component is required to pass the course.

Your lab grade will be broken into the following components:

Submission of group results on the AU Landing	Participation mark	Group discussion	Lab report, submitted 3 weeks after lab
50%	10%	15%	25%

Group Research Projects

Students will form groups of 2-4 people (depending on class size) to work on specific topics on Day 1 and Day 2. Each group should assign specific tasks to each group member: one person will take the measurements using specific instruments, another person will record notes or take photographs. Importantly, the task of uploading group results will require a degree of responsibility as it affects the whole group (50% of your lab grade will be derived from your uploaded results).

At the end of the lab, we will have a group discussion of results from Day 1 (limnology) and each group will present their data, followed by a discussion and suggestions of how to present the data in the lab report.

Result submission: To obtain full marks, submit all completed tables with your results, as well as good quality photographs as well as other results (Hobo logger, Game camera photos) to the AU Landing. Results will be marked per group.

Group discussions

On Day 4 , each group (from Day 1) will present their data tables, with suggestions on how to analyze their results. This discussion will be marked and constitute 15% of your lab mark.

How to write a lab report for BIOL 345

Laboratory reports are very similar to the format that scientists use to communicate research findings. Reading some scientific papers in ecology journals will help you to write your own lab reports.

The format for lab reports will be as follows: Title, Abstract, Introduction, Materials and Methods, Results, Discussion, and References. This is a common structure for the presentation of primary research.

Scientific writing avoids direct quotes for citations. Paraphrase instead.
Example:
Incorrect: … Smith and Cornish (2011) reported "a higher amount of iron in all lakes close to the mining activities" which suggests…
Correct: … all lakes adjacent to the mining areas were found to have an increased iron content (Smith and Cornish 2011), therefore …

Use past tense and passive style consistently. E.g. "…flow speed was measured…".

- Title (3). The title tells the reader in one sentence what the lab report is about. The first letter is capitalized and all other words are lower case (unless a proper name or generic name). The title should not exceed 120 characters.
- Abstract (15). The abstract provides a brief summary of the research including the research hypothesis (or research question), methods (briefly), results, and (briefly) main conclusions. All main results (data) must be included in the abstract. Do not cite references in the abstract. The purpose of the abstract is for a reader to quickly learn the research contents and determine if the paper is relevant to their interests. Abstracts should not be longer than 200 words.
- Introduction (15). The introduction should provide a general background to the research that familiarizes readers with relevant information on your topic and is supported by citations. In the final paragraph the introduction should briefly state the rationale and objectives of the study, as well as the research hypothesis.
- Materials and Methods (7) The methods inform the reader how you did your research. There should be enough detail that someone could repeat the study. A clear description of the experimental design and sampling is required. Describe the study site and the location. The methods section is written in passive style and in the past tense. Do not include results in the methods section.

Results (15). Describe your group results in the past tense. Do not interpret your data in the results section. To complement the text you should, where appropriate, include numbered tables and figures (e.g., Table 1 or Figure 1) that clearly and accurately represent the results. Tables are used to display true data. Graphs are used to highlight relationships between data. Tables and figures (photos or graphs) should stand alone, meaning that the reader should be able to look at the table without reading the paper, and gain a general understanding of the results. That means that the title or figure legend must be informative and complete, and axes should have titles and units as well. Each figure and table should be mentioned in the text. The purpose of the text is to point out trends in the data. Do not simply repeat the data from tables and figures in the text but mention the trends that you observe (without interpretation).

Discussion (20). In the discussion you will interpret the data in relation to your original objective or hypothesis. A discussion is a comparison of your results with those in the literature, therefore use ample citations in this section. Move from the specific to the general (i.e. start with the interpretation of your own results, before you start generalizing). Relate your interpretations to current knowledge on the topic and if possible future research direction. Do not merely reiterate the results. The discussion should compare results to those of other researchers, identify inadequacies of methods or analysis (if applicable), suggest explanations of unexpected results, and include some brief conclusions at the end. Avoid general statements with little relevance for your study.

References (15). In the reference section list the references specifically cited in the paper. All citations must be in the reference section, and all references must be cited. For this lab report we will follow CSE style in the Name-Year format: https://libguides.athabascau.ca/citationguide/othercitationstyles. Your lab report needs at least five primary references (articles in scholarly journals).

Language, structure, grammar, style (10). Reading some scientific papers will give you a good idea about scientific style.

Note: SI units are mandatory for all lab reports and science writing in general. Imperial units, such as miles, pounds, inches, degrees Fahrenheit etc. will incur mark deductions.

Resources

MASTERING BIOLOGY on your BIOL 345 course page has some helpful hints on graphs and data.
The links below are helpful for deciding what type of graph or chart you should select:

https://nces.ed.gov/nceskids/help/user_guide/graph/howto.asp
https://www.skillsyouneed.com/num/graphs-charts.html
https://www.doc.govt.nz/documents/science-and-technical/docts32entire.pdf

You can create graphs with Excel. If you haven't worked with Excel a lot, try the following resources: https://www.excel-easy.com/

ONLINE IDENTIFICATION KEYS

The following apps will help us learn how to identify various organisms in the field. Remember that no AI is perfect, and we should be checking the suggestions against field guides and other provided resources.

iNaturalist is a website and phone app database recording observations of all living things. It encourages the participation of a wide variety of nature enthusiasts, and by connecting these different perceptions and expertise of the natural world, iNaturalist is an international initiative created to connect people regardless of background and instead, learn about the natural world and beauty around them. They have a great getting started guide found here: https://www.inaturalist.org/pages/getting%252Bstarted
The main website is here: https://www.inaturalist.org/

Seek https://www.inaturalist.org/pages/seek_app. Using the inaturalist database, Seek, can be used to identify organisms found in the area.

The Cornell Lab of Ornithology has produced many apps, including Edbird and Merlin ID.

Ebird https://ebird.org/home: The app allows you to keep a checklist of the birds you see while you are birding, you can also look at local data and store photos and sound recordings.

Merlin Bird ID https://merlin.allaboutbirds.org/:
Merlin is a bird field guide that allows you to identify the bird by photograph, description or sound recording. The app contains many pictures, sound recordings and information on birds.

Field Guide for Everything
App https://fieldguide.ai/figureshttps://medium.com/@andrporemski/getting-started-with-fieldguide-c967d364e258
Answer two questions: "what's this?" and “where can I find it?" through the use of pattern recognition and crowd-sourced information. You can use it on the phone or the computer, which is relatively accurate in its ID.

GPS/Mapping

Avenza Maps: https://www.avenzamaps.com/mobile-maps?campaignid=10221828697&adgroupid=102940455500&adid=453328850375&gclid=EAIaIQobChMIhazCIJ6j-AIVgT6tBh1WJwDsEAAYASAAEgLCcfD_BwE
Avenza Maps are offline maps, GPS locations and digital maps stored on your mobile devices. You can locate yourself ***without*** the Internet or network

connections. Allowing it to be used even in the most remote places.

Conservation and Hunting groups have developed apps like **iHunter AB** (https://www.ihunterapp.com/) or **Huntstand (**https://www.huntstand.com/). You can purchase digital copies of Landowner maps and use them to mark waypoints, see directions and weather, and sunrise and sunset information.

Garmin has phone apps for their newer GPS devices and smartwatches; you can track your hikes and send information to family and friends in emergencies.

Alberta specific Apps

Report invasive species with https://www.eddmaps.org/ **EDDMapS** is used to report invasive species

Alberta Discovery Guide also has an app https://www.albertadiscoverguide.com/ It is an excellent way to find various lakes and other conservation sites around Alberta.

Misc

Ducks Unlimited has an app; Useful for Duck identification and finding wetlands. https://www.ducks.org/hunting/mobile-apps

Arboreal https://www.arboreal.se/en/ Measure tree heights with your phone, as recommended by Ducks Unlimited.

APPENDICES

Simple Key to Major Producers (plants and plant-like organisms)

1a	Chlorophyll absent, not green	Not a photosynthetic producer e.g. Fungi)
1b	Chlorophyll present, usually green	2
2a	Unicellular or cell filaments (no tissues), primarily microscopic, primarily aquatic or semi-aquatic	3
2b	Multicellular organisms	4
3a	Prokaryotic cells (lacking nuclei)	Cyanobacteria
3b	Eukaryotic cells (with nuclei) present, sex cells unicellular	Protista, algae
4a	Composed of symbiotic fungi and algae or cyanobacteria; not usually green; terrestrial	Lichens
4b	Sex organs multicellular; mostly terrestrial	5 (Plantae)
5a	Vascular tissue absent; thallus (body) dorsal-ventrally flattened and on ground; not usually leaf-like but if so without mid-rib	Liverworts
5b	Vascular tissue present, not as above	6
6a	Erect thallus with small scale-like leaves with mid-ribs, reproduces by spores borne in a capsule on a stalk above the leaves	Mosses
6b	Not as above	7
7a	Seeds absent, spores borne under leaves or in strobulia	Ferns and fern allies
7b	Seeds present	8
8a	Flowers absent, seeds naked in woody cones; leaves usually needle-like	Gymnosperms
8b	Flowers present, seeds enclosed in fruits	9 (Angiosperms)
9a	Flower parts in 3s of multiples of 3, seeds with one cotyledon, leaves usually narrow and long with parallel venation	Monocotyledons
9b	Flower parts in 4s or 5s or multiples thereof, seeds with two cotyledons, leaves usually broad with netted venation	Dicotyledons

Common plant species of the Athabasca area

General grouping	Common name	Scientific name
Gymnosperms	White spruce	Picea glauca
	Jack Pine	Pinus banksiana
	Balsam fir	Abies balsamea
	Tamarack	Larix laricina
Monocots	Brome grass	Bromus sp.
	Two-leaved Solomon's-seal	Maianthemum canadense
	Western wood lily	Lilium philadelphicum var. andinum
Woody dicots	Green alder	Alnus crispa
	Beaked hazelnut	Corylus cornuta
	Willow	Salix spp.
	Red-osier dogwood	Cornus stolonifera
	Buffaloberry	Shepherdia canadensis
	Saskatoon	Amelanchier alnifolia
	Pin cherry	Prunus pensylvanica
	Choke cherry	Prunus virginiana
	Prickly rose	Rosa acicularis
	Raspberry	Rubus idaeus
	Wild red currant	Ribes triste
	Low bush-cranberry	Viburnum edule
	Common snowberry	Symphocarpos albus
	Bracted honeysuckle	Lonicera involucrata
	Common blueberry	Vaccinium myrtilloides
	Lingonberry	Vaccinium vitis-idaea
	Bearberry	Arctostaphylos uva-ursi
	Balsam poplar	Populus balsamifera ssp. balsamifera
	Trembling aspen	Populus tremuloides
	Birch	Betula papyrifera

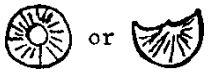
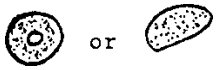
Herbaceous dicots	Twinflower	Linnaea borealis
	Northern bedstraw	Galium boreale
	Wild sarsaparilla	Aralia nudicaulis
	Spreading dogbane	Apocynum androsaemifolium
	Bunchberry	Cornus canadensis
	Bishop's cap	Mitella nuda
	Common harebell (bluebell)	Campanula rotundifolia
	Wild strawberry	Fragaria virginiana
	Dewberry	Rubus pubescens
	Wild strawberry	Fragaria virginiana
	Wild vetch	Vicia americana
	Early blue violet	Viola adunca
	Fireweed	Epilobium angustifolium
	Pink wintergreen	Pyrola asarifolia
	Common dandelion	Taraxacum officinale
Miscellaneous	Common scouring rush	Equisetum hyemale
	Common horsetail	Equisetum arvense
	Lady fern	Athyrium filix-femina
	Pelt lichen	Peltigera spp.
	Club lichen	Cladonia spp.
	Knight's plume	Ptilium crista-castrensis
	Stair step moss	Hylocomium splendens
	Big red stem	Pleurozium schreberi

Key to Some Deciduous Trees and Shrubs of the Boreal Forest with Simple Leaves

1a	Compound leaf (leaf divided into leaflets connected with thin "stems" such as roses) or needle leaves (e.g. tamarack)	These plants are **not** dealt with in this key
1b	Simple leaf (may have lobes but all parts of leaf touch the petiole)	2
2a	Leaves opposite on stem	3
2b	Leaves alternate on stem	8
3a	Leaves 3-lobed, maple-like, 5-10 cm wide	Viburnum
	(i) Deeply 3-lobed leaves, shrub up to 2 m	High Bush Cranberry
	(iii) Shallowly 3-lobed leaves, shrub up to 3.5 m	Low Bush Cranberry
	Note; Flowers for both are white, small and in flattened clusters; neither is a true cranberry.	
3b	Leaves not as above	4
4a	Leaves more or less heart-shaped; flowers small, densely clustered, purple, pink and white	Lilac (non-native)
4b	Leaves not as above	5
5a	Papery scales present at twig bases	7
5b	Papery scales not present at twig bases	6
6a	Leaves with veins that strongly tend to follow leaf edges; whitish flowers in flat-topped clusters, red twigs and/or branches	Red Ozier Dogwood
6b	Leaves with veins not as above; leaves 1.5- 5 cm long, silver-downy with brown scales beneath; red or orange berries, soapy when crushed (hence alternate name; Soapberry)	Buffalo Berry
7a	Midvein prominent, leaf 5-15 cm long	Honeysuckle
	(i) Upper pair of leaves fused to form cup for yellow to orange-red flowers	Twining Honeysuckle
	(ii) Flowers paired, dull yellow and flanked below by two leaf-like bracts; inky black berries	Bracted Honeysuckle
7b	Leaves 1.2 – 4 cm long, round to oval; white or pink bell-shaped flowers	Snowberry
8a	Leaves at least three times as long as wide; several species, flowers produced in catkins, found in moist to wet areas	Willow
8b	Leaves not as above	9
9a	Leaves doubly toothed or lobed	10
9b	Leaves not as above	13

10a	Leaves lobed	11
10b	Leaves not lobed	12
11a	Branches with thorns or spines; 3-5 lobed with round toothed margins, 2- 6 cm wide, new stems often prickly; green to purple edible berry	Gooseberry
11b	Without thorns or spines; deeply 3-5 lobed, coarsely toothed margins, greenish-purple flowers in long drooping clusters; red edible berry	Currant
12a	Leaves triangular or egg shaped, and flat at base, teeth absent near stalk	Birch
	(i) Tree, up to 25 m tall, bark white and peels easily in old trees	White or paper birch
	(ii) Small tree 2.5-3 m tall, bark is thin, shiny, dark red brown, covered with sticky glands, leaves are yellow-green dotted with sticky glands	Water birch
12b	Leaves broadly oval, 5-10 cm long with veins deeply impressed below; shrub up to 2.5 m tall; edible nut enclosed in two hairy green bracts extending 2.5 cm beyond the nut	Beaked Hazelnut
13a	Leaves finely toothed, twig when bruised has a distinct odor (bitter)	Cherry
	(i) Teeth ending in a hair-like point, flowers in erect solid- looking cylindrical cluster; ripe berries dark purple	Chokecherry
	(ii) Leaves often slightly folded along midrib; flowers five to seven per cluster on stalks 7-10 cm long; ripe berries red	Pincherry
13b	No pungent odor when twigs are bruised	14
14a	Veins wandering, prominent midrib	Poplar
	(i) Leaves; nearly circular 3-5 cm wide; petiole flattened and usually longer than leaf blade	Aspen Poplar (Trembling Aspen, Quaking Aspen)
	(ii) Leaves; egg-shaped with a sharp tip, 7-12 cm long, stalk round	Balsam Poplar (Black Poplar)
14b	Veins straight and evenly spaced; leaves are almost circular, finely toothed but **without** serrations near the base, dark purple berries in a cluster, shrub 1-4.5 m high	Saskatoon Berry

Generalized Key for Some Groups of Fungi from the Athabasca Region
Thallus = body of fungus.

1a	Thallus with gills on undersurface of cap	Agaricaceae	
1b	Gills absent	2	
2a	Thallus with pores on undersurface of cap	3	
2b	Pores absent	4	
3a	Stalk central; cap spongy; grows on ground	Boletaceae	
3b	Stalk short and lateral or absent; cap leathery or hard; usually on wood	Polyporaceae (Bracket fungi)	
4a	Fungus a solid, ball-shaped structure, usually on ground	Gasteromycetales (Puffballs)	
4b	Not a solid ball	5	
5a	Fungus cup-shaped; no gills; pores or projections	Discomycetes (cup-fungi)	
5b	Fungus not cup-shaped	6	
6a	Fungus stalked with a convoluted cap	Helvellaceae (include morels)	
6b	Not as above	7	
7a	Fungi with projections growing upwards of downwards	8	
7b	Fungi with no projections	9	
8a	Fungus consisting of club-shaped projections growing upwards (on wood)	Clavariaceae (Club-fungi)	
8b	Fungus possessing many fine tooth-shaped projections growing downwards (usually on wood)	Hydnaceae (Tooth-fungi)	
9a	Fungus a shapeless mass; jelly-like when moist; leathery when dry (on wood)	Tremellales (Jelly fungi)	
9b	Fungus thin and leathery with a smooth sporing surface, no gills or pores. Often on wood and in shape resembling a bracket fungus	Thelephoraceae	

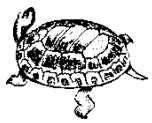
Key to Major Animal Groups

1a	Vertebral column (backbone) present	2 (Phylum Chordata)
1b	Vertebral column absent	8
2a	Hair present	Class Mammalia (mammals)
2b	Hair absent	3
3a	Feathers present	Class Aves (birds)
3b	Feathers absent	4
4a	Fins present	5
4b	Fins absent	7
5a	Jaws absent	Class Agnatha (jawless fishes)
5b	Jaws present	6
6a	Gills covered by an operculum	Class Osteicthyes (bony fishes)
6b	Gills not covered by an operculum	Class Chondrichthyes (sharks, rays)
7a	Skin scales present, eggs develop on land or internally	Class Reptilia (turtles, snakes, lizards)
7b	Skin scales absent, eggs	Class Amphibia (frogs,

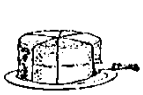
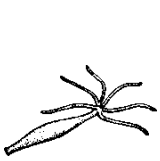







usually develop in water salamanders)

8a	Growth form asymmetrical or radially symmetrical (in a circular manner around a central point, as in a bicycle wheel); usually colonial; spicules and ostia present, aquatic	Phylum Porifera (sponges)	  
8b	Growth form radially symmetrical; discrete individuals or colonial	9	 
8c	Body bilaterally symmetrical (right and left sided)	10	 
9a	Tentacles present with cnidocysts, aquatic	Phylum Cnidaria (hydra & medusa)	
9b	Usually 5 divisions, tube feet present	Phylum Echinodermata	
10a	Jointed legs present, chitinous exoskeleton	11 (Phylum Arthropoda)	
10b	Not as above	15	
11a	Antennae absent, usually 4 pairs of legs	Class Arachnida (spiders, ticks, harvestmen)	
11b	Antennae present	12	
12a	One pair of antennae	13	
12b	Two pair of antennae, first pair often reduced; usually aquatic; various numbers of legs	Class Crustacea (shrimp, crabs)	

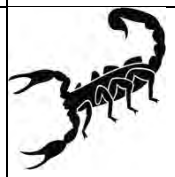
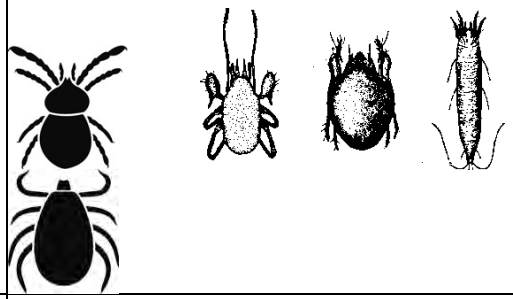
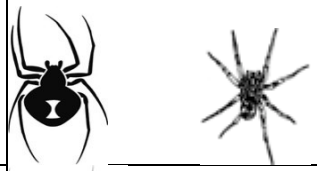
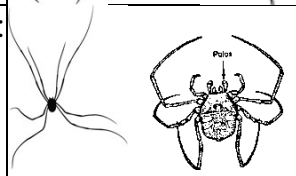
13a	Walking legs, 3 pairs, usually with 2 or 4 wings as adults	Class Insecta (grasshoppers, beetles, flies, wasps)
13b	Walking legs, 6 or more pairs	14

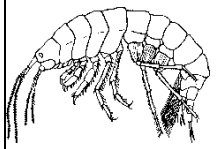
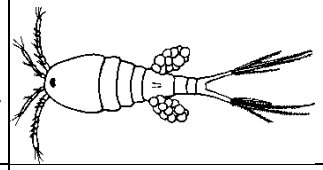
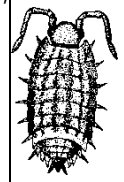
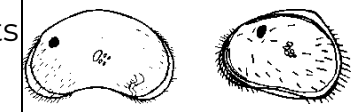
14a	Legs, 1 pair for each body segment	Class Chilopoda (centipede)
14b	Legs, 2 pairs for each body segment	Class Diplopoda (millipede)
15a	Calcareous shell present (if absent, one or two pairs o tentacles	16 (Phylum Mollusca)
15b	Calcareous shell absent; no tentacles	17
16a	Shell in two symmetrical parts	Class Bivalvia (clams)
16b	Shell in spiral shape (or shell absent)	Class Gastropoda (snails, slugs)
17a	Worm-like	18
17b	Not worm-like	22
18a	Body not segmented	19
18b	Body segmented	20
19a	Flattened shape, eye spots	Phylum Platyhelminthes Class Turbellaria (flatworms)
19b	Cylindrical in cross section	Phylum Nematoda (round worms)
20a	Legs or prolegs present	Various insect larvae (Phylum, Arthropoda, Class Insects)
20b	Legs or prolegs absent	21 (Phylum Annelida)
21a	Setae present, cylindrical	Class Oligochaeta (earthworms, bristle worms)
21b	Setae absent, flattened, suckers	Class Hirudinea (leeches)

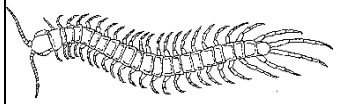
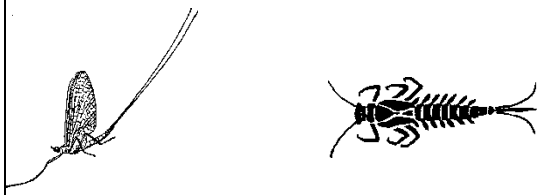
22a	Body segmented, cilia present, microscopic, aquatic	Phylum Rotatoria (rotifers)	
22b	Body not as above, microscopic, microscopic, aquatic	Phylum Gastrotricha (gastrotrichs)	

Outline of Phylum Arthropoda See also: www.bugguide.net

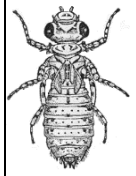
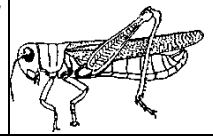
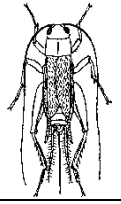
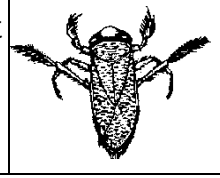
These are the names and basic descriptions of the various arthropods that you are likely to encounter in the Athabasca area. You do not have to remember the names but the descriptions and drawings will help you identify the animals you encounter.

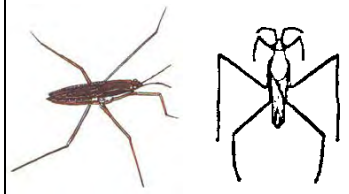
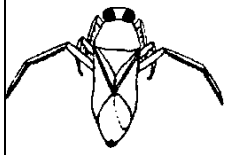
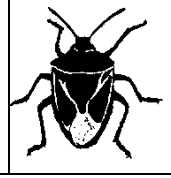
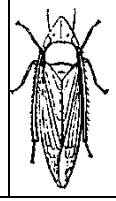
Class	Order	Family	Description	Illustration
Arachnida			arachnids: chelicerate (“pinchers”) mouthparts, palps, 4 pairs of legs, no antennae, primarily predaceous	
	Acari		mites, ticks: basically one body part, 3 pairs of legs in larval stages, fused mouth parts, mostly terrestrial; herbivores, scavengers, predators, parasites; ticks all blood parasites on vertebrates	
	Araneae		spiders: 2 body parts, 6-8 eyes, silk, poison glands, all predaceous	
	Opiliones		harvestmen/daddy-long-legs: 1 body part, 2 eyes, scent glands, no silk or poison glands, predators and scavengers	

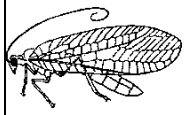
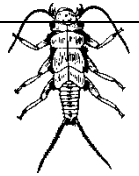
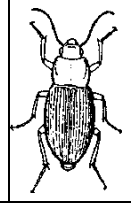
Crustacea			crustaceans: 2 pairs of antennae, mandibulate (“chewing”) mouthparts, legs variable but biramous, mostly aquatic	
	Amphipoda		side-swimmers/scuds: laterally compressed, many legs, long first antennae, herbivores and scavengers	
	Copepoda		copepods, e.g. *Cyclops*: cylindrical body, single eye, two posterior rami, females often with two egg sacs, filter feeders	
	Isopoda		sowbugs/woodlice: terrestrial, small first pair of antennae, plant scavengers	
	Cladacera		water-fleas, e.g. *Daphnia*: laterally flattened, large antennae for swimming, head free of carapace, terminal spine, filter feeders	
	Ostracoda		ostracods/seed-shrimp: laterally compressed, all parts within carapace, small, often green, filter feeders	

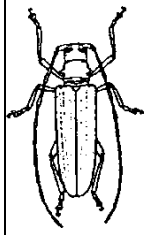
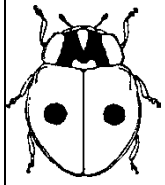
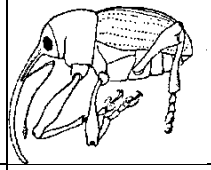
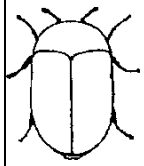
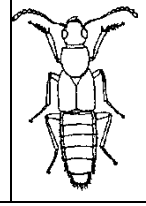
Chilopoda			centipedes: 1 pair antennae,1 pair of legs per segment, poison glands, terrestrial, all predaceous	
Diplopoda			millipedes: 1 pair antennae, 2 pair of legs per segment, terrestrial, all herbivorous	
	Collembola		springtails: ventral springing apparatus, without wings, very small but often numerous; considered as a sister group of the insects; herbivores and scavengers	
Insecta			insects: 1 pair antennae, mandibulate mouthparts, 3 pairs of legs, with or without wings, 3 body parts (head, thorax with legs and wings, abdomen)	
	Ephemeroptera		mayflies: aquatic larvae with external wing buds, abdomen with gills, herbivores and filter feeders; adults with 2 pair wings, hind ones small and triangular, long abdominal cerci, do not feed	 A L

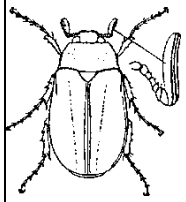
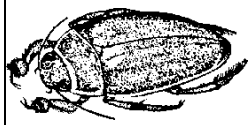
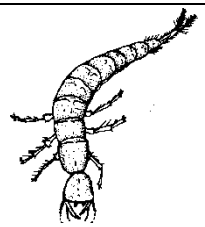
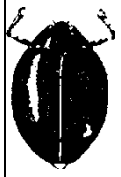
	Odonata		dragonflies, damselflies: adults with 2 pair of elongate wings, large compound eyes, elongate abdomen, predaceous; dragonflies with wings to side, damselflies usually held behind	 A

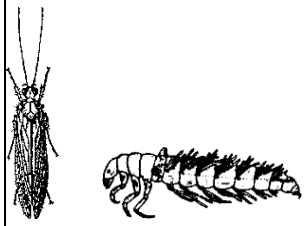
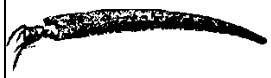
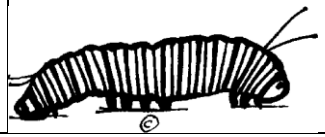
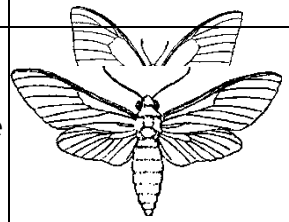
	Odonata (continued)		aquatic larvae with folding mouth parts, predaceous; dragonflies with internal anal gills, damselflies with three external posterior gills; no pupa	  L
	Orthoptera		grasshoppers, crickets: simple metamorphosis, terrestrial, jumping hind legs, 2 pair wings if present; herbaceous	 
	Hemiptera (Heteroptera)		true bugs, piercing-sucking mouthparts arising at front of head, wings held flat over abdomen, basal portion of front wings are thickened and leathery, apical portions are membranous, hind wings are membranous, simple metamorphosis	
		Belastomatidae	giant water bugs: aquatic, very large, dark brown, predaceous	
		Corixidae	corixids/water boatmen: aquatic, first pair of legs short and scoop- like, large lateral eyes; herbaceous	

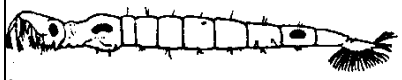
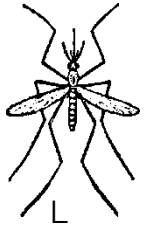
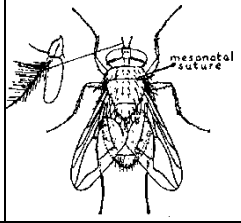
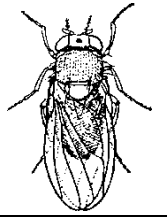
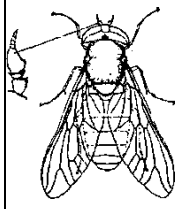
		Gerridae	gerrids/water striders: aquatic on surface of water, very long 2nd and 3rd legs, predaceous	
		Notonectidae	notonectids/backswimmers: aquatic, swim upside down, dorsal side light-coloured, very long back legs, predaceous	
		Pentatomidae	pentatomids/stink bugs: terrestrial, broad shield-like shape, triangular scutellum (between wings), suck plant juices	
	Homoptera		homopterans: piercing-sucking mouth parts arising from back of head; 2 pair membranous or leathery wings held at side of body, herbaceous, simple metamorphosis; terrestrial	
		Aphididae	aphids: with or without wings; usually green, small with 2 “tubes” on back of abdomen	
		Cercopidae	froghoppers, spittlebugs: usually green, larvae covered in frothy bubbles (spittle)	

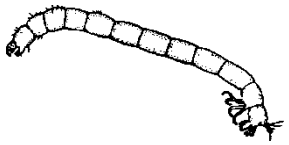
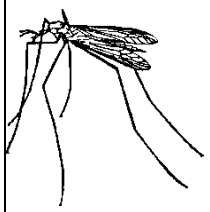
	Neuroptera	This and all the following have complete metamorphosis, i.e. with pupae.	lacewings, ant-lions: adults with 4 membranous wings, great many cross-veins and extra branches; lace wing adults are green, both larvae and adults feed on aphids	
	Plecoptera		Stoneflies: larvae are aquatic with lateral gills; adults have long antennae and long wings	  A L
	Coleoptera		beetles: adults with 2 pair of wings, front ones usually hard and cover the folded back pair; larvae usually with legs, see illustrations to right	L 
	Terrestrial forms	Carabidae	ground beetles: adults large with antennae slender and shorter than the body, terrestrial, predacious	

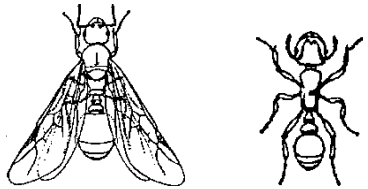
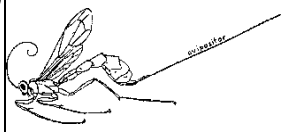
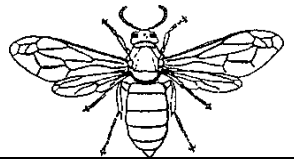
		Cerambycidae	long-horned beetles: adults large with extremely long antennae, larvae feed under back of decaying trees	
		Coccinellidae	lady(bird) beetles: adults usually orange with black spots; larvae usually purple with long mandibles; both feed on aphids	 
		Curculionidae	snout beetles/weevils: adults black or gray with elbowed antennae on the “snout”; primarily seed eaters	
		Dermestidae	skin, carpet and larder beetles: adults small often black with lateral tan stripe, primarily scavengers	 
		Staphylinidae	rove beetles: adults with short wing covers, both larvae and adults are predaceous	

		Scarabaeidae	scarab beetles: antennae club-like but consisting of leaf-like plates, often feed on dung	
		Silphidae	carrion beetles: terrestrial, adults usually black with lateral orange stripes, often feed on dead vertebrates	
	Aquatic forms	Dytiscidae	predaceous diving beetles: aquatic, adults dorsal-ventrally compressed, usually shiny and black; larvae with large sickle- shaped mandibles; predaceous	 A  L
		Gyrinidae	whirling beetles: aquatic, adults small black, on surface of water; eyes split for seeing above and below; move in fast circling patterns, usually in groups	

	Trichoptera		caddisflies: adults brown with 4 hairy wings and long antennae; aquatic larvae build cases of silk, often covered with stones or plant debris	 A L 
	Lepidoptera		butterflies and moths: larvae/caterpillars are herbaceous; adults with scale wings and usually sucking mouthparts L 	 B M

	Diptera		true flies: larvae are legless maggots, adults with 1 pair of wings and 1 pair of halteres (balancing organs)	
		Asilidae	robber flies: adults with long thin abdomens, predaceous	
		Chaoboridae	phantom midges: larvae aquatic, clear bodies with 4 air sacs, predaceous	 L
		Culicidae	mosquitoes: larvae/wrigglers aquatic, filter feeders; adult females with piercing-sucking mouthparts, females primarily feed on blood	 A  L
		Muscidae	muscid flies, e.g. house fly, stable fly: many species; many larvae and adults feed on dung or decaying vegetation	 
		Tabanidae	horse and deer flies, greenheads: adults heavy bodied, antennae short, wings may have patterns (deer flies), adult females feed on blood from mammals	

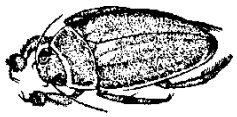
		Tentapiidae (Chironomidae)	non-biting midges/chironomids: adults resemble mosquitoes but no sucking mouthparts; larvae are aquatic with proleg just ventral to head, often with gills at posterior	L 
		Tipulidae	crane flies: adults large and resemble mosquitoes, antennae long and thread-like	
		Syrphidae	flower flies: adults often have black and yellow stripes that resemble bees or wasps	
	Hymenoptera		sawflies, wasps, bees, ants: 4 membranous wings, front and back wings linked with a hooking mechanism	
		Apidae	bumble bees, honey bees: adults large, usually with many yellowish hairs, venomous, feed on pollen and nectar	

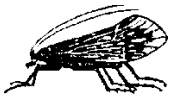
		Formicidae	ants: elbowed antennae, reproductive adults with wings, workers (all females) wingless, predaceous and herbivorous on seeds	
		Ichneumonidae	ichneumons: adults with long thin bodies, females with long ovipositors, parasitoids (larvae feed on insects)	
		Vespidae	paper wasps: adults large black with yellow or cream stripes, wings held folded lengthwise, venomous and aggressive, predators and scavengers	 

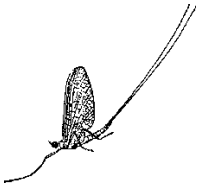
Key to Some Orders of Adult Insects

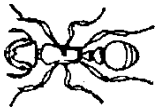
1a	Arthropod (jointed appendages and chitinous exoskeleton) with more or less than six legs	Not an adult insect
1b	Arthropods with six legs	2
2a	With wings	3
2b	Without wings	14
3a	One pair of wings	Diptera (true flies)

3b	Two pairs of wings (one pair may be hidden under wing covers)	4
4a	Front pair of wings (elytra), hard and shell-like covering the folded hind wings	Coleoptera (beetles)
4b	Not as above	5
5a	Both pairs of wings covered by obvious hairs or scales (flattened hairs)	6
5b	At least one pair of wings transparent. Not obviously covered with scales or hairs (though hairs may be seen with a microscope)	7
6a	Wings covered with coloured scales, mouth parts usually a coiled tube	Lepidoptera (butterflies and moths)
6b	Wings covered with hairs, mouth parts not as above	Trichoptera (caddisflies)

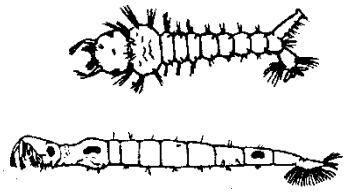
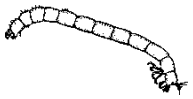
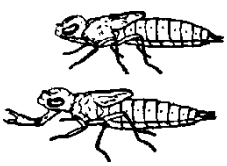


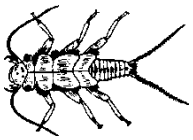
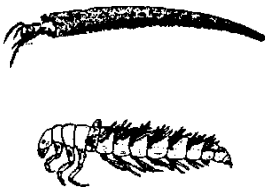
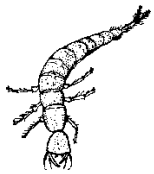


7a	Hind wings small and connected to front wings by microscopic hooks, abdomen usually connected to thorax by a slender "waist"	Hymenoptera (ants, wasps, bees)	
7b	Wings not as above	8	
8a	Mouthparts tube-like and enlarged for piercing and sucking, often folded underneath body	9	
8b	Mouthparts not as above	10	
9a	Mouthparts arising from front of head, first pair of wings opaque at the base and membranous at the apex	Hemiptera (plant bugs, water boatmen, giant water bugs)	
9b	Mouthparts arising from back of head, forewings either leathery or membranous but of uniform consistency	Homoptera (aphids, cicadas)	
10a	Femur of hind pair of legs broad, adapted for leaping	Orthoptera (grasshoppers, crickets)	
10b	Hind legs not as above	11	
11a	Both pairs of wings similarly elongate and membranous	12	
11b	Wings membranous but unequal in size	13	
12a	Long antennae	Neuroptera (lacewings, snakeflies)	
12b	Short antennae	Odonata (dragonflies, damselflies)	
13a	Hind wings small and triangular, three terminal abdominal processes, antennae short	Ephemeroptera (mayflies)	

13b	Hind wings larger than forewings, abdomen with pair of stout appendages, antennae long	Plecoptera (stoneflies)	
14a	Abdomen connected to thorax by a slender "waist"; antennae elbowed	Hymenoptera (ants)	
14b	Small oval-shaped body, sucking mouthparts; found on plants.	Homoptera (aphids)	

Key to Some Aquatic Orders of Insect Larvae

1a	Without jointed thoracic legs: with abdominal prolegs, or entirely legless but with distinct head and mouthparts.	Diptera (true flies)	
1b	With jointed thoracic legs	2	
2a	Larvae with wings developing externally (wing pads present)	3	
2b	Larvae with wings developing internally and so not visible	6	
3a	Mouthparts combined into a piercing and sucking beak, which is directed beneath the head; first pair of wings leathery at base and membranous apically	Hempitera (Go to *i* for Families)	
	*i*a Front legs "scoop-like" and without apical claws	Corixidae (water boatmen)	
	*i*b Front legs not as above	*ii*	
	*ii*a Wings present: swim on back	Notonectidae (backswimmers)	
	*ii*b Wings usually absent or very reduced: "skate" on surface of water	Gerridae (water striders)	
3b	Mouth parts not as above	4	
4a	Mouth parts when extended much longer than the head: at rest folded like a hinge, extending between the bases of the forelegs	Odonata (Go to *i* for suborders (damselflies and dragonflies)	

	ia Three broad, leaf-like appendages (gills) at end of abdomen	Zygoptera (damselflies)	
	ib Three small spines at end of abdomen	Anisoptera (dragonflies)	
4b	With long slender tails; mouthparts **not** longer than the head	5	
5a	Gills mainly under the thorax; tarsal claws, two; “tails”, two	Plecoptera (stoneflies)	
5b	Gills mainly on the sides of the abdomen: tarsal claws single; “tails” generally three	Ephemeroptera (mayflies)	
6a	Generally living in a portable case; without terminal abdominal spiracles	Trichoptera (caddisflies)	
6b	Without a portable case; usually with terminal abdominal spiracles	Coleoptera (beetles)	

ALBERTA LAND AND FOREST SERVICES —— INDIVIDUAL TREE VOLUME TABLE (1994)

Table 35. Merchantable length (m) from 0.30 m stump height to 5.0 cm top dib

SPECIES: WHITE SPRUCE
NATURAL REGIONS: 1 TO 6, 12, 13, 15, 16

DBHOB (cm)	STUMP DOB (cm)	TOTAL TREE HEIGHT (m) 3.1-5.0	5.1-7.0	7.1-9.0	9.1-11.0	11.1-13.0	13.1-15.0	15.1-17.0	17.1-19.0	19.1-21.0	21.1-23.0	23.1-25.0	25.1-27.0	27.1-29.0	29.1-31.0	31.1-33.0	33.1-35.0	35.1-37.0	37.1-39.0	Predicted HT (m)
5.1- 7.0	5.3- 7.5	0.75	1.28	1.82	2.36	2.89	3.43	3.96	4.50	5.04	5.57	6.11	6.65	7.18	7.72	8.26	8.79	9.33	9.87	6.5
7.1- 9.0	7.6- 9.8	1.71	2.79	3.86	4.94	6.01	7.09	8.17	9.24	10.32	11.40	12.47	13.55	14.63	15.70	16.78	17.86	18.93	20.01	8.5
9.1-11.0	9.9- 12.1	2.16	3.48	4.80	6.12	7.44	8.76	10.09	11.41	12.73	14.06	15.38	16.70	18.02	19.35	20.67	21.99	23.31	24.64	10.4
11.1-13.0	12.2- 14.4	2.42	3.88	5.35	6.82	8.29	9.75	11.22	12.69	14.16	15.63	17.10	18.56	20.03	21.50	22.97	24.44	25.91	27.38	12.3
13.1-15.0	14.5- 16.7	2.59	4.15	5.71	7.28	8.84	10.41	11.97	13.54	15.11	16.67	18.24	19.80	21.37	22.93	24.50	26.07	27.63	29.20	14.0
15.1-17.0	16.8- 19.0	2.71	4.34	5.97	7.61	9.24	10.88	12.51	14.15	15.78	17.42	19.05	20.69	22.32	23.96	25.59	27.23	28.86	30.50	15.6
17.1-19.0	19.1- 21.3	2.79	4.48	6.16	7.85	9.54	11.22	12.91	14.60	16.28	17.97	19.66	21.35	23.03	24.72	26.41	28.10	29.78	31.47	17.1
19.1-21.0	21.4- 23.6	2.86	4.58	6.31	8.04	9.76	11.49	13.22	14.95	16.67	18.40	20.13	21.86	23.58	25.31	27.04	28.77	30.50	32.22	18.4
21.1-23.0	23.7- 25.9	2.91	4.66	6.42	8.18	9.94	11.70	13.46	15.22	16.98	18.74	20.50	22.26	24.02	25.78	27.54	29.30	31.06	32.82	19.7
23.1-25.0	26.0- 28.2	2.95	4.73	6.51	8.30	10.09	11.87	13.66	15.44	17.23	19.02	20.80	22.59	24.38	26.16	27.95	29.73	31.52	33.31	20.8
25.1-27.0	28.3- 30.5	2.98	4.78	6.59	8.40	10.20	12.01	13.82	15.63	17.44	19.24	21.05	22.86	24.67	26.47	28.28	30.09	31.90	33.71	21.9
27.1-29.0	30.6- 32.7	3.00	4.83	6.65	8.48	10.30	12.13	13.96	15.78	17.61	19.43	21.26	23.09	24.91	26.74	28.56	30.39	32.21	34.04	22.8
29.1-31.0	32.8- 35.0	3.02	4.86	6.70	8.54	10.39	12.23	14.07	15.91	17.75	19.59	21.44	23.28	25.12	26.96	28.80	30.64	32.48	34.32	23.6
31.1-33.0	35.1- 37.3	3.04	4.89	6.75	8.60	10.46	12.31	14.17	16.02	17.88	19.73	21.59	23.44	25.30	27.15	29.00	30.86	32.71	34.57	24.4
33.1-35.0	37.4- 39.6	3.05	4.91	6.78	8.65	10.52	12.38	14.25	16.12	17.98	19.85	21.72	23.58	25.45	27.31	29.18	31.05	32.91	34.78	25.1
35.1-37.0	39.7- 41.8	3.06	4.93	6.81	8.69	10.57	12.45	14.32	16.20	18.08	19.95	21.83	23.70	25.58	27.46	29.33	31.21	33.08	34.96	25.7
37.1-39.0	42.0- 44.1	3.07	4.95	6.84	8.73	10.61	12.50	14.39	16.27	18.16	20.04	21.93	23.81	25.70	27.58	29.47	31.35	33.24	35.12	26.3
39.1-41.0	44.2- 46.4	3.07	4.97	6.86	8.76	10.65	12.55	14.44	16.34	18.23	20.12	22.01	23.91	25.80	27.69	29.59	31.48	33.37	35.26	26.8
41.1-43.0	46.5- 48.7	3.08	4.98	6.88	8.79	10.69	12.59	14.49	16.39	18.29	20.19	22.09	23.99	25.89	27.79	29.69	31.59	33.49	35.39	27.2
43.1-45.0	48.8- 50.9	3.08	4.99	6.90	8.81	10.72	12.63	14.53	16.44	18.35	20.25	22.16	24.07	25.97	27.88	29.79	31.69	33.60	35.50	27.6
45.1-47.0	51.0- 53.2	3.08	5.00	6.91	8.83	10.74	12.66	14.57	16.49	18.40	20.31	22.22	24.13	26.05	27.96	29.87	31.78	33.69	35.60	28.0
47.1-49.0	53.3- 55.4	3.08	5.00	6.93	8.85	10.77	12.69	14.61	16.53	18.44	20.36	22.28	24.20	26.11	28.03	29.95	31.86	33.78	35.69	28.3
49.1-51.0	55.6- 57.7	3.08	5.01	6.94	8.86	10.79	12.71	14.64	16.56	18.48	20.41	22.33	24.25	26.17	28.09	30.01	31.94	33.86	35.78	28.6
51.1-53.0	57.8- 60.0	3.08	5.01	6.95	8.88	10.81	12.74	14.67	16.59	18.52	20.45	22.37	24.30	26.23	28.15	30.08	32.00	33.93	35.85	28.9
53.1-55.0	60.1- 62.2	3.08	5.02	6.95	8.89	10.83	12.76	14.69	16.62	18.55	20.48	22.41	24.34	26.27	28.20	30.13	32.06	33.99	35.92	29.1
55.1-57.0	62.3- 64.5	3.07	5.02	6.96	8.90	10.84	12.78	14.71	16.65	18.58	20.52	22.45	24.39	26.32	28.25	30.18	32.12	34.05	35.98	29.3
57.1-59.0	64.6- 66.7	3.07	5.02	6.97	8.91	10.85	12.79	14.73	16.67	18.61	20.55	22.49	24.42	26.36	28.30	30.23	32.17	34.10	36.04	29.5
59.1-61.0	66.8- 69.0	3.07	5.02	6.97	8.92	10.87	12.81	14.75	16.69	18.64	20.58	22.52	24.46	26.40	28.34	30.28	32.21	34.15	36.09	29.7
61.1-63.0	69.1- 71.2	3.07	5.02	6.97	8.93	10.88	12.82	14.77	16.71	18.66	20.60	22.55	24.49	26.43	28.37	30.32	32.26	34.20	36.14	29.9
63.1-65.0	71.3- 73.5	3.06	5.02	6.98	8.93	10.88	12.84	14.78	16.73	18.68	20.63	22.57	24.52	26.46	28.41	30.35	32.30	34.24	36.19	30.0
65.1-67.0	73.6- 75.7	3.06	5.02	6.98	8.94	10.89	12.85	14.80	16.75	18.70	20.65	22.60	24.54	26.49	28.44	30.39	32.33	34.28	36.23	30.1
67.1-69.0	75.8- 77.9	3.05	5.02	6.98	8.94	10.90	12.86	14.81	16.76	18.72	20.67	22.62	24.57	26.52	28.47	30.42	32.37	34.32	36.27	30.2
69.1-71.0	78.1- 80.2	3.05	5.01	6.98	8.95	10.91	12.87	14.82	16.78	18.73	20.69	22.64	24.59	26.54	28.50	30.45	32.40	34.35	36.30	30.3
71.1-73.0	80.3- 82.4	3.04	5.01	6.98	8.95	10.91	12.87	14.83	16.79	18.75	20.70	22.66	24.61	26.57	28.52	30.48	32.43	34.38	36.33	30.4
73.1-75.0	82.5- 84.6	3.04	5.01	6.98	8.95	10.92	12.88	14.84	16.80	18.76	20.72	22.68	24.63	26.59	28.55	30.50	32.46	34.41	36.37	30.5
75.1-77.0	84.8- 86.9	3.03	5.01	6.98	8.95	10.92	12.89	14.85	16.81	18.77	20.73	22.69	24.65	26.61	28.57	30.52	32.48	34.44	36.39	30.6
77.1-79.0	87.0- 89.1	3.03	5.00	6.98	8.95	10.92	12.89	14.86	16.82	18.79	20.75	22.71	24.67	26.63	28.59	30.55	32.50	34.46	36.42	30.6
79.1-81.0	89.2- 91.3	3.02	5.00	6.98	8.96	10.93	12.90	14.87	16.83	18.80	20.76	22.72	24.68	26.65	28.61	30.57	32.53	34.49	36.45	30.7

ALBERTA LAND AND FOREST SERVICES —— INDIVIDUAL TREE VOLUME TABLE (1994)

Table 2. Gross total volume (m^3) from 0.00 m stump height to 0.0 cm top dib

SPECIES: BALSAM POPLAR
NATURAL REGIONS: 1 TO 6, 12, 13, 15, 16

DBHOB (cm)	STUMP DOB (cm)	TOTAL TREE HEIGHT (m) 3.1-5.0	5.1-7.0	7.1-9.0	9.1-11.0	11.1-13.0	13.1-15.0	15.1-17.0	17.1-19.0	19.1-21.0	21.1-23.0	23.1-25.0	25.1-27.0	27.1-29.0	29.1-31.0	31.1-33.0	33.1-35.0	35.1-37.0	37.1-39.0	Predicted HT (m)
1.1- 3.0	1.9- 3.8	0.0004	0.0007	0.0009	0.0011	0.0013	0.0016	0.0018	0.0020	0.0022	0.0025	0.0027	0.0029	0.0031	0.0034	0.0036	0.0038	0.0040	0.0043	4.2
3.1- 5.0	3.9- 5.9	0.0019	0.0028	0.0038	0.0047	0.0057	0.0067	0.0076	0.0086	0.0096	0.0105	0.0115	0.0125	0.0134	0.0144	0.0154	0.0163	0.0173	0.0183	6.5
5.1- 7.0	6.0- 8.0	0.0041	0.0063	0.0084	0.0105	0.0127	0.0148	0.0170	0.0191	0.0213	0.0234	0.0256	0.0277	0.0299	0.0321	0.0342	0.0364	0.0385	0.0407	8.6
7.1- 9.0	8.1- 10.2	0.0073	0.0110	0.0148	0.0185	0.0223	0.0261	0.0298	0.0336	0.0374	0.0412	0.0450	0.0488	0.0526	0.0564	0.0602	0.0640	0.0678	0.0716	10.4
9.1-11.0	10.3- 12.3	0.0112	0.0170	0.0228	0.0287	0.0345	0.0403	0.0462	0.0520	0.0579	0.0638	0.0696	0.0755	0.0814	0.0873	0.0931	0.0990	0.1049	0.1108	12.0
11.1-13.0	12.4- 14.5	0.0161	0.0243	0.0326	0.0410	0.0493	0.0576	0.0660	0.0743	0.0827	0.0911	0.0995	0.1079	0.1163	0.1247	0.1331	0.1415	0.1499	0.1583	13.5
13.1-15.0	14.6- 16.7	0.0217	0.0329	0.0441	0.0554	0.0666	0.0779	0.0892	0.1005	0.1118	0.1231	0.1344	0.1458	0.1571	0.1685	0.1799	0.1912	0.2026	0.2140	14.8
15.1-17.0	16.8- 18.9	0.0282	0.0427	0.0573	0.0719	0.0865	0.1011	0.1158	0.1304	0.1451	0.1598	0.1745	0.1892	0.2039	0.2187	0.2334	0.2482	0.2630	0.2777	15.9
17.1-19.0	19.0- 21.1	0.0355	0.0538	0.0721	0.0904	0.1088	0.1272	0.1457	0.1641	0.1826	0.2011	0.2196	0.2381	0.2566	0.2752	0.2937	0.3123	0.3309	0.3495	17.0
19.1-21.0	21.3- 23.4	0.0436	0.0660	0.0885	0.1110	0.1336	0.1562	0.1789	0.2015	0.2242	0.2469	0.2696	0.2924	0.3151	0.3379	0.3607	0.3835	0.4063	0.4291	17.9
21.1-23.0	23.5- 25.7	0.0525	0.0795	0.1066	0.1337	0.1609	0.1881	0.2153	0.2426	0.2699	0.2973	0.3246	0.3520	0.3794	0.4068	0.4342	0.4617	0.4892	0.5166	18.8
23.1-25.0	25.8- 28.0	0.0623	0.0942	0.1263	0.1584	0.1906	0.2228	0.2551	0.2874	0.3197	0.3521	0.3845	0.4169	0.4494	0.4818	0.5143	0.5468	0.5794	0.6119	19.5
25.1-27.0	28.1- 30.3	0.0728	0.1101	0.1475	0.1851	0.2227	0.2603	0.2980	0.3358	0.3735	0.4114	0.4492	0.4871	0.5250	0.5629	0.6009	0.6389	0.6769	0.7149	20.2
27.1-29.0	30.5- 32.7	0.0841	0.1272	0.1704	0.2137	0.2571	0.3006	0.3441	0.3877	0.4314	0.4750	0.5187	0.5625	0.6062	0.6500	0.6939	0.7377	0.7816	0.8255	20.8
29.1-31.0	32.8- 35.1	0.0962	0.1454	0.1948	0.2444	0.2940	0.3437	0.3934	0.4433	0.4931	0.5430	0.5930	0.6430	0.6930	0.7431	0.7932	0.8434	0.8935	0.9438	21.4
31.1-33.0	35.2- 37.5	0.1091	0.1649	0.2208	0.2770	0.3332	0.3895	0.4459	0.5023	0.5588	0.6154	0.6720	0.7287	0.7854	0.8421	0.8989	0.9557	1.0126	1.0695	21.9
33.1-35.0	37.6- 39.9	0.1227	0.1854	0.2484	0.3115	0.3747	0.4380	0.5014	0.5649	0.6285	0.6921	0.7557	0.8194	0.8832	0.9470	1.0108	1.0747	1.1387	1.2026	22.4
35.1-37.0	40.1- 42.4	0.1372	0.2072	0.2775	0.3480	0.4186	0.4893	0.5601	0.6310	0.7019	0.7730	0.8441	0.9152	0.9864	1.0577	1.1290	1.2004	1.2718	1.3432	22.8
37.1-39.0	42.5- 44.9	0.1524	0.2301	0.3081	0.3863	0.4647	0.5432	0.6218	0.7005	0.7793	0.8581	0.9370	1.0160	1.0951	1.1742	1.2533	1.3325	1.4118	1.4911	23.2
39.1-41.0	45.0- 47.4	0.1683	0.2541	0.3403	0.4266	0.5131	0.5998	0.6866	0.7734	0.8604	0.9474	1.0346	1.1218	1.2090	1.2964	1.3838	1.4712	1.5587	1.6463	23.5
41.1-43.0	47.5- 49.9	0.1850	0.2793	0.3739	0.4688	0.5638	0.6590	0.7544	0.8498	0.9453	1.0409	1.1367	1.2325	1.3283	1.4243	1.5203	1.6164	1.7125	1.8087	23.8
43.1-45.0	50.0- 52.4	0.2025	0.3056	0.4091	0.5128	0.6168	0.7209	0.8251	0.9295	1.0340	1.1386	1.2433	1.3480	1.4529	1.5578	1.6629	1.7679	1.8731	1.9783	24.1
45.1-47.0	52.6- 55.0	0.2207	0.3330	0.4457	0.5587	0.6719	0.7853	0.8989	1.0126	1.1264	1.2403	1.3544	1.4685	1.5827	1.6970	1.8114	1.9259	2.0404	2.1550	24.3
47.1-49.0	55.1- 57.6	0.2397	0.3615	0.4838	0.6065	0.7293	0.8524	0.9756	1.0990	1.2225	1.3461	1.4699	1.5937	1.7177	1.8417	1.9659	2.0901	2.2144	2.3388	24.5
49.1-51.0	57.7- 60.2	0.2594	0.3911	0.5234	0.6560	0.7889	0.9220	1.0553	1.1887	1.3223	1.4560	1.5898	1.7238	1.8579	1.9920	2.1263	2.2606	2.3951	2.5296	24.8
51.1-53.0	60.4- 62.9	0.2799	0.4219	0.5645	0.7074	0.8507	0.9942	1.1379	1.2817	1.4257	1.5699	1.7142	1.8586	2.0031	2.1478	2.2925	2.4374	2.5823	2.7273	24.9
53.1-55.0	63.0- 65.5	0.3011	0.4537	0.6070	0.7607	0.9147	1.0689	1.2233	1.3780	1.5328	1.6878	1.8429	1.9981	2.1535	2.3090	2.4646	2.6203	2.7761	2.9320	25.1
55.1-57.0	65.7- 68.2	0.3230	0.4866	0.6509	0.8157	0.9808	1.1461	1.3117	1.4775	1.6435	1.8096	1.9759	2.1423	2.3089	2.4756	2.6424	2.8093	2.9764	3.1435	25.3
57.1-59.0	68.3- 70.9	0.3457	0.5206	0.6963	0.8725	1.0490	1.2258	1.4029	1.5802	1.7577	1.9353	2.1132	2.2911	2.4693	2.6475	2.8259	3.0045	3.1831	3.3618	25.4
59.1-61.0	71.1- 73.7	0.3691	0.5556	0.7431	0.9310	1.1194	1.3080	1.4970	1.6861	1.8755	2.0650	2.2547	2.4446	2.6347	2.8248	3.0152	3.2056	3.3962	3.5869	25.5
61.1-63.0	73.8- 76.4	0.3932	0.5918	0.7913	0.9914	1.1919	1.3927	1.5938	1.7952	1.9968	2.1985	2.4005	2.6027	2.8050	3.0074	3.2101	3.4128	3.6157	3.8187	25.6
63.1-65.0	76.6- 79.2	0.4180	0.6290	0.8409	1.0535	1.2665	1.4798	1.6935	1.9074	2.1216	2.3359	2.5505	2.7653	2.9802	3.1953	3.4106	3.6260	3.8415	4.0572	25.7
65.1-67.0	79.3- 82.0	0.4436	0.6672	0.8919	1.1173	1.3432	1.5694	1.7959	2.0228	2.2498	2.4771	2.7047	2.9324	3.1603	3.3884	3.6166	3.8450	4.0736	4.3023	25.8
67.1-69.0	82.1- 84.8	0.4698	0.7065	0.9443	1.1829	1.4219	1.6614	1.9011	2.1412	2.3816	2.6221	2.8630	3.1040	3.3452	3.5866	3.8282	4.0700	4.3119	4.5540	25.9
69.1-71.0	85.0- 87.7	0.4968	0.7468	0.9981	1.2502	1.5027	1.7557	2.0091	2.2628	2.5167	2.7709	3.0254	3.2801	3.5349	3.7900	4.0453	4.3008	4.5564	4.8122	26.0
71.1-73.0	87.8- 90.6	0.5245	0.7882	1.0533	1.3192	1.5856	1.8525	2.1198	2.3874	2.6553	2.9234	3.1919	3.4605	3.7294	3.9985	4.2678	4.5373	4.8070	5.0769	26.0
73.1-75.0	90.7- 93.5	0.5529	0.8306	1.1098	1.3898	1.6705	1.9516	2.2331	2.5150	2.7972	3.0797	3.3624	3.6454	3.9287	4.2121	4.4958	4.7797	5.0637	5.3480	26.1
75.1-77.0	93.6- 96.4	0.5820	0.8740	1.1677	1.4622	1.7574	2.0531	2.3492	2.6457	2.9425	3.2396	3.5370	3.8347	4.1326	4.4308	4.7291	5.0277	5.3265	5.6255	26.2
77.1-79.0	96.5- 99.3	0.6118	0.9185	1.2269	1.5363	1.8463	2.1569	2.4679	2.7794	3.0911	3.4032	3.7156	4.0283	4.3412	4.6544	4.9678	5.2814	5.5953	5.9093	26.2
79.1-81.0	99.5-102.3	0.6422	0.9640	1.2875	1.6120	1.9372	2.2630	2.5893	2.9160	3.2431	3.5705	3.8982	4.2262	4.5545	4.8830	5.2118	5.5408	5.8700	6.1995	26.3

UNDERLINED VALUES IN THE MIDDLE PORTION OF THE TABLE REPRESENT VOLUMES FOR AVERAGE HEIGHT-DIAMETER TREES.