Training Manual for Field Biologists in Papua New Guinea

Andrew L. Mack and Debra D. Wright

The cover painting is by PNG artist Ted Deko, commissioned by D. Wright, and is the logo of the non-profit Green Capacity, dedicated to biological research and training, especially in PNG.

Website: www.pngibr.org

Website: www.greencapacity.org

Website: www.conservationinternational.org

Copyright © 2011
Andrew L. Mack and Debra D. Wright
All rights reserved.
This publication is available for free educational and non-profit use.
No part of this publication may be reproduced for profit in any form or any means, electronically, mechanically, by photocopying, or otherwise, without the prior permission of the copyright owners.

Recommended Citation:
Mack, A. L. and D. D. Wright. 2011. Training Manual for Field Biologists in Papua New Guinea. Green Capacity Publication One, USA. Free PDF download from www.pngibr.org, www.greencapacity.org or www.conservationinternational.org.

Author contact information: amack@greencapacity.org and dwright@greencapacity.org

TABLE OF CONTENTS

ACKNOWLEDGEMENTS 5
CHAPTER 1: Introduction 6
CHAPTER 2: Safety 8
CHAPTER 3: Introduction to Field Research 12
CHAPTER 4: Basic skills 16
CHAPTER 5: Plants 30
CHAPTER 6: Birds 43
CHAPTER 7: Mammals 54
CHAPTER 8: Herpetofauna 67
CHAPTER 9: Insects 74
CHAPTER 10: Introduction to Sampling and Experimental Design 78
CHAPTER 11: Introduction to Data Analysis 87
CHAPTER 12: Advanced Statistics for Field Biologists 97
CHAPTER 13: Proposal Writing 117
CHAPTER 14: How to Write a Scientific Paper 127
CHAPTER 15: How to Prepare an Oral Presentation or Poster 136
LITERATURE CITED 144
APPENDIX 1. Data Sheets 148
APPENDIX 2. Random Number Table 159
APPENDIX 3. Statistical Tables 168

Dedicated to the spirit of "Uncle" Paul Igag
1964-2010

May your accomplishments, your passion for PNG birds,
and your jovial goodwill continue to inspire others.

You are sorely missed.

ACKNOWLEDGEMENTS

Our very first student training course in June 1996!

Production of this manual was initially subsidized in 1996 by a grant to Conservation International from USAID. Since then it has been a collaborative effort by many people who have helped teach field courses for Conservation International and the Wildlife Conservation Society 1996-2007. The authors founded and led these courses, aided by guest instructors including: David Bickford, Paul Igag, Brian Kennedy, Susan Klimas, Silvia Lomascolo, Kurt Merg, Vojtech Novotny, Alex Reich, Stephen Richards, Leonardo Salas, Ed Scholes, Ross Sinclair and Miriam Supuma. Many of these guest instructors contributed to earlier chapter drafts in this manual. The statistics chapters are modified from a handout by Peter Feinsinger. Editing for this version has been funded by the CI RAP Program; we are very grateful to Stephen Richards for enabling this and for comments on this version.

We give special thanks to donors supporting the field courses, particularly The Christensen Fund and The MacArthur Foundation, and wish to thank the Honourable Mal Smith for 20 years of constant support in PNG.

We are especially grateful for the enthusiastic support and comments of the many course trainees who field-tested versions of this manual every year since 1996. Several hundred students have used different versions of this manual. Many have made helpful suggestions for improvement.

The field courses have been held throughout PNG and we wish to give our deep thanks to the many landowners in PNG who have allowed us in their forests over the years. Many have helped us and the students in ways too numerous to list.

The Biology and Environmental Sciences faculty at the University of Papua New Guinea have supported the training program since its inception and have made many tremendous and enthusiastic contributions. These include assistance scheduling courses, selecting students to participate, and ensuring that participants obtain credit from their hard efforts toward graduation.

As many of the initial instructors were visitors to PNG, we also thank the PNG Department of Immigration, the Department of Environment and Conservation, and the National Research Institute for processing the necessary visas and permits to allow biologists from many nations to come to PNG and help transfer knowledge to students.

This manual is the result of combined contributions from these donors, colleagues, students, government officials, and landowners. We hope that by making this manual downloadable for free, we can return some of the goodwill, financial resources and work that so many people have invested in the training programs that created this manual.

CHAPTER 1: Introduction

This manual is designed for students beginning their early experiences with field biology, particularly in Papua New Guinea (PNG). The manual is derived from field courses taught and led by the editors Mack and Wright in PNG 1996-2007 in PNG with hundreds of students and conservation professionals, many of whom have made suggestions for improvement. Each course also had guest instructors who made helpful contributions and suggestions (see Acknowledgments). In this final version of the manual we combine materials from all of the courses and have re-written chapters for greater clarity and consistency. We believe the manual will prove useful to young field biologists anywhere, not just PNG. It will be particularly useful to students in other tropical nations like PNG, with poorly-developed research and educational resources. Much of the world uses text books with a strong slant on biology from the United States and Europe. We think there is no harm in occasionally producing textbooks with the slant coming from other parts of the world.

PNG is blessed with an extraordinary living laboratory, some of the last and healthiest tropical forests left on our planet. Other countries have fancy indoor laboratories where biologists can manipulate DNA or colonies of organisms. But few have such a rich forest on their doorstep. This book is written to help get a student out of the classroom and into the forest where the student can begin the transformation to becoming a scientist. Anyone can be a scientist—it just means applying scientific methods to solve problems and obtain new information. Your employer does not make you a scientist; your work does. We want to help jumpstart your learning and set you on the path to becoming a scientist. PNG needs scientists, just as it needs doctors and teachers. PNG already has enough politicians!

This manual is not intended to replace material presented at any educational institution. This manual is to act as an adjunct to formal educational coursework currently available to university students. We have not included detailed citations and bibliographic material in this manual. New information is always coming out and exhaustive citations can make reading tedious. Instead, for each field course we will provide an updated CD with an extensive bibliography including abstracts and copies of publications; if you would like a copy please contact the authors.

The future of nations like PNG depends upon wise decisions of resource management. Poor decisions could leave little beyond a ruined environment and a poor lifestyle for future generations. For example, a logging company could destroy the land of some people so their children could never grow food there again. On the other hand, good decisions can ensure growth into a modern, economically-secure nation with a healthy, high quality-of-life for its citizens. For example, another logging company, run by landowners, might harvest enough timber to support a healthy economy without destroying

the land for future use. The information used to base such strategies and decision-making should come from scientific data. With good, reliable, unbiased information, people are more likely to make good decisions. Without good information they can only guess, or be deluded by unscrupulous exploiters. We think the scientist's role is crucial. As PNG grows, more and more people will turn to science and PNG's scientists for help with their decision-making.

There are two basic approaches in the study of ecology in PNG and elsewhere: observational approaches and experimental approaches (Ludwig and Reynolds 1988). In this course we are mainly concerned with observational approaches-- e.g., the description of biotas at different locations in PNG. Experimental approaches require some sort of manipulation wherein a manipulated sample or population (the treatment group) is compared with the un-manipulated sample or population (the control group). However, many of our observational studies can be treated as experimental studies, even though we do not directly manipulate certain variables. For example, we may use the observational approach to measure cuscus populations in two similar regions that differ in hunting intensity by the landowners; we can compare the two groups to look for differences just as we would with treatment and control groups in an experimental study.

There are three general sets of basic skills field biologists need to master which we address in this manual:

- ***field and taxonomic skills,*** such as identifying birds or plants, mapping, taking measurements, laying out transects and preparing specimens;
- ***analytical skills,*** such as comparing vegetation at two different altitudes and drawing a conclusion about which is more diverse; and
- ***communication skills,*** such as preparing proposals and reports that effectively and clearly make the points you wish to make.

To the degree that you can master all of these you will be a well-rounded scientist. Every student has different aptitudes, and we encourage students to emphasize those areas in which they have the greatest strength. However, we especially encourage students to develop their taxonomic skills. There are extremely few scientists anywhere in the world with advanced taxonomic expertise. Many groups of organisms can only be identified by a handful of people, if that many, in the world. If you develop taxonomic proficiency with any group of organisms in PNG or other tropical nation, be it snails, worms, or mammals, you could quickly become one of the leading authorities in the world. Even trained "parataxonomists" without formal university training can play vital roles in developing science in PNG (Bassett et al. 2004). Quite simply, there are too few people in the world that can identify the organisms that live outside North America and Europe. If we cannot identify an organism we cannot begin to understand it, nor understand how to conserve it.

For conservation there are three fundamental biological questions that every land-planner needs to ask:

- ***What plants and animals live in a specific area?*** Or, in other words, what plants and animals will be affected by decisions regarding a particular land-use decision? If we do not know what organisms depend upon a piece of land, and what they need for their survival, we cannot possibly assess the potential impacts of any modifications to that land. Special field skills are necessary to scientifically answer this question.
- ***Do the plants and animals living in a specific area differ from those living in other areas?*** In other words, how special is the community living in an area compared to other areas? We might wish to take special care of species or groups of species (communities) that are rare, or restricted in their distribution, whereas we might be less concerned about a species that is widespread and abundant. The ability to answer this

question is largely dependent upon mastering the skills used for the first question and then applying some analytical procedures to the field data.

- ***Will a certain use, or did a previous use, of land or resources affect (negatively or positively) specific plants or animals?*** This can be a very complicated question to answer confidently, but it is important that scientists attempt to do so. The basic skills to begin answering this question, and the other questions, are dealt with in this manual.

The questions outlined above need to be asked regarding every development project in PNG if the country is to meet the Constitutional mandate that PNG's *"natural resources and environment be conserved and used for the collective benefit of us all, and to be replenished for the benefit of future generations."* Many other nations have similar mandates for the protection of their environment. At the root of this protection comes good science.

CHAPTER 2: Safety

Before we begin we need to talk about safety. Field work in New Guinea is not particularly more dangerous than any other way you might spend your time. However, fieldwork often takes you to remote areas where medical attention, if needed, is not readily available. Therefore, it is important to be more safety-conscious than you might be day-to-day in your home. Furthermore, this work does carry some risks you might not be familiar with if you have not already done much fieldwork in New Guinea. Please read the following tips carefully and follow them.

Always work with a companion. This is extremely important should you suffer any injury-- your companion can care for you and go to get help if needed. You may also be less likely to get lost if you are with others.

Let others know when to expect your team back. Make sure other people, not with you, know where you are working and when to expect you back so they can look for you if you do not return on time.

Be well-equipped with safety gear when in the field. Take a compass if you will be away from mapped trails. Carry a small flashlight in case you cannot get back to camp before dark. Carry a raincoat or other protection in case you get stuck in the forest overnight (some extra food is also good to have). Carry water in country where clean water is scarce. Carry first-aid materials if you will be far from your base camp, including at a minimum ace bandages in case of snake bite and medical tape to make butterfly bandages in case of severe cuts. You can find your way home with a GPS if you have a waypoint stored for your camp so you should carry one of these.

Be prepared for a medical emergency evacuation. Whenever possible ensure you have a working radio or satellite phone to use in case of emergency. Know how to contact emergency services, such as helicopter evacuation. Know your location (GPS fix) and have a medical evacuation point established before there is any emergency (know where the nearest possible helicopter landing site is). Take an emergency first aid course as part of your preparation as a field biologist and whenever possible carry a comprehensive first aid kit with medical reference books.

If you are working in new country be sure to ***hire a local guide.*** You do not want to get lost in New Guinea's vast wilderness areas.

The rugged terrain of New Guinea creates hazards. Avoid steep slopes and cliffs if you think you might fall or slip from them. Use your own judgment about what is safe-- be conservative. Don't take shortcuts if they lead you into unfamiliar and hazardous terrain. Be very cautious around rivers-- they can rise and flood very quickly. Do not camp below highest flood level (never on gravel or sand bars!). If you are working on a river keep your ears open for coming floods, watch the dry places between river rocks (if they start to get wet, get away from the river), keep an escape route in mind in case you need to get away from a flood. If possible, avoid moving into steep canyons where there is no escape route. Remember, it does not have to be raining where you are for a river to flood; rains far

away in mountains can cause flash floods in the lowlands.

The open waters of New Guinea contain hazards as well. Do not go to sea in ill-equipped boats or if the weather looks bad. Carry emergency water, flotation devices, food, a map and compass and GPS. A satellite phone in a boat when you are lost or stranded could be your salvation; keep it dry. Inspect motors and fuel supplies yourself before setting out to sea. Too many people have been lost on even short runs between islands because of a breakdown or inexcusably running out of fuel. Don't just trust the boatman you hire-- check to make sure the boat is seaworthy and don't set out if you are dissatisfied.

Be very careful if you are collecting snakes. Learn how to tell the venomous species and avoid capturing them or risking their bites. If you are uncertain if a snake is venomous it is best to leave it alone. Do not collect snakes unless you have been trained by a herpetologist.

Avoid other toxic or dangerous organisms. Do not swim where there might be crocodiles. Avoid scorpions, bees, wasps or other stinging insects. Many stinging hymenoptera build their nests on the undersides of shrub leaves-- you will learn to keep an eye open for such nests once you have bumped into a couple! Learn to recognize *Semecarpus* species (Anacardiaceae) as many can give you a bad skin rash.

Be careful if you are using a bush knife. The most dangerous thing in the forest is a careless person with a bush knife!

Cleanliness is extremely important. Many small cuts and scrapes can become infected, leading to debilitating ulcers that can make you very sick or even be fatal. This is less likely if you wash your body with antiseptic soap every day. Thoroughly clean any injury, even small ones. Keep cleaning injuries, particularly if any minor indication of infection appears. Have your companions or survey group-leader or medical officer examine any wounds or potential infections. Clean kitchen habits and clean drinking and washing water will help avoid gastro-intestinal problems. Have dry, clean clothes to wear in camp. Use talcum powder or other skin powders in camp to help dry and soothe skin. Skin that is constantly wet will develop painful fungal infections. This is especially true for feet—once you are back in camp dry them thoroughly and put on powder and dry socks or you *will* get foot fungus.

Have a medical/first aid kit in camp. Do not go on a field survey if you do not have a complete medical kit. This should include all sorts of materials for treating wounds, topical antibiotics, antibiotic pills, malaria medicine, rehydration salts, grille lotion to treat skin fungus, etc. Have good medical books (e.g., "Where there is no doctor") if you will not be with a trained medical officer. Have a radio or other means of quickly reaching a doctor or calling for emergency evacuation. Be equipped to treat not only your survey team, but also your local assistants or any landowners in the region of your camp that might arrive needing help.

Be aware of chemical hazards. There are a number of hazardous chemicals used on surveys. Do not get formalin on your skin; use rubber gloves and avoid inhaling formalin fumes. Do not smoke near ethanol or fuels.

Snake bite. There are many things a good field worker should learn about first aid, from dressing wounds to preventing malaria. Entire books are written about first aid and you should get at least one and study it thoroughly before starting field work. But many books do not describe the best way to treat snake bite, especially in Papua New Guinea. ALL of the venomous snakes in PNG are elapids which have predominantly neurotoxic venoms. Because PNG does not have vipers, the basic first aid for any venomous snake bite will be the same. Where there are vipers you would need to treat viper bites differently from elapid bites.

In the case of a snakebite, first make sure the victim cannot be bitten again, get them away from the snake. Note the identity of the snake if possible, but make sure the victim is safe and no one else is at risk. Keep the victim calm, get them

to lie down, with the bite lower than the heart. Most snake bites happen in extremities-- either on the leg or hand/arm. The danger increases as the neurotoxin migrates from the site of the bite closer to the central nervous system where it can cause paralysis that stops breathing or interferes with heartbeat.

As soon as possible after being bitten wrap an ace bandage starting about 5-8cm from the bite on the side of the extremity toward the heart, then wrap the bandage tightly toward the heart, all the way up the extremity, then back again toward and over the bite. The idea is to compress the lymphatic system so the venom will not migrate toward the heart. Wrap tightly, but not so tight as to cut off blood flow to the extremity. Get the extremity wrapped then immobilize the extremity, the less movement the slower the venom will move to where it will cause more problems.

Keep the wrapping on until a qualified doctor with anti-venom can unwrap it. Once wrapped your task is to get the victim to a hospital where anti-venom can be administered. If no anti-venom is available, it might be possible for an experienced doctor to carefully control the movement of venom so that normal extractive processes of the liver and kidneys can cope with the toxins without a fatality, provided not too much venom was delivered and the wrapping effectively keeps the venom from core organs. Maybe.

The most important thing is not to be bitten in the first place. Wear closed shoes or preferably high boots, especially at dusk and night when elapids might be more active. Do not handle snakes unless fully trained and competent. Be ever vigilant where you walk and place your hands. Have an evacuation plan and ability to get to anti-venom before even starting fieldwork. Study first aid and be trained to handle emergencies of all kinds that might happen while doing biological field research.

MOST IMPORTANTLY: Be Aware, Think, Be careful, Use common sense! Most accidents in the field occur when people do something stupid-- they fall, they cross a river at the wrong place, they panic when they think they are lost, they climb a tree that is weak, etc. Most of these accidents are completely avoidable through simple caution. It is important to know your limits-- do not try to jump over a ravine if it is too far for you to jump, even if your companion jumped it with no problem. It is always best to err on the side of caution if you think some activity is dangerous.

The forests of New Guinea are beautiful and wonderful places to be. If they are alien to you they might seem foreboding and dangerous, but they really are not. Relax and enjoy your opportunities to be in the forest-- around the world there are billions of people stuck in offices, in factories, and in windowless rooms who would love to be outside in the forest. You are extremely fortunate to have the opportunity to conduct fieldwork in such a beautiful place. Most people do not have fresh air to breathe, or clean water to drink; they hear machines and other people not birds and insects; they spend their lives away from nature because nature has been eradicated from their surroundings. Most of these people yearn to have a little more nature around them. As biologists in New Guinea we can count ourselves as among the luckiest people in the world-- do not let a few insect bites, scratches, or wet clothes let you forget how lucky you are!!

CHAPTER 3: Introduction to Field Research

Introduction

Inventories or surveys (the two terms are often interchangeable) are intended to find all of the species, or as close as possible, in a given area. In most cases it will be impossible to truly find *all* species resident in an area. You can think of survey results as a single snapshot of some portion of the biological community at one site, at one particular time. Because surveys and inventories are usually concerned with documenting presence, they often include specimen collecting. A properly prepared specimen provides an unequivocal proof of presence. It is important to note that the contrary is not true. The lack of an observation or specimen does not document absence of a species from a location. We can document presence but only surmise absence.

Inventories are usually made at sites where biological communities are poorly known, or to document a biota before it is perturbed by some human intervention. Surveys are particularly important in unique habitats, where development pressures are intensifying. Inventories and monitoring not only tell us about communities at specific sites, they also help build our knowledge of the regional flora and fauna in general. At present we know so little about PNG's spectacular biota that it is difficult to predict what species will be found at any site without performing field surveys to find out. Only after much more survey work in PNG will scientists be able to begin to accurately predict what species are found where. How true do you think this is in other countries? Do we really know the actual distribution of any but the rarest and most local species?

In contrast, biological monitoring usually entails multiple field sessions over time. Monitoring is usually done to detect changes (or the lack of changes) in biological communities through time. Because specimen collecting can itself change communities, it is important to be particularly careful if planning any collecting that is part of a monitoring project. Monitoring is often used to detect the effects of something-- like the effect of mine tailings in a river, of a logging project, or even climate change. Monitoring usually entails a more quantitative assessment of population of the monitored taxa, not just presence. We can only monitor a small subset of the total biodiversity found at any site in PNG. For example, we might monitor the bird community and use that as an indicator for other communities we cannot monitor (like flies, worms, land snails, etc.). If we record new extirpations (the word for local extinctions) in the bird community, we *might* suspect that a certain land use is having negative effects on other communities as well.

"Process" of designing field research

Every research project is unique and thus each project has its own methods and analytical analysis. It is not possible to put in a book all of the methods one can use, even if you confined it to a fairly narrow topic, like the study of terrestrial ants in the Lakekamu Basin. But we hope to introduce the novice to enough techniques so they can get started and adapt and

build their methods toolkit as they learn. Science is a creative process as much as any art. Just as we cannot make a manual that will turn you into a successful painter, we cannot make a manual that will make you a successful biologist. But there are techniques artists can learn, and there are techniques biologists can learn. These fundamentals are where we start. As you advance you will learn to design and create your own goal-oriented field techniques.

The first step of any research project, be it a one day mini-project or a career-long study, is to **identify your question.** What do you want to learn? Once you have done this, everything else follows—the proposal, the experimental design, the execution, the analysis, and the communication of results. You should be prepared at any stage of your research to answer this question: What are you trying to learn? If you are having trouble designing your project, step back to this question, "*What do you want to learn?*" and work forward from there. A good field biologist does this often because it is very easy to become derailed and side-tracked by other questions that arise.

The question might simply be "I am trying to learn what species of birds live in this forest." Or, it might be much more complicated: "I am trying to learn how the mercury in runoff from mine tailings moves through the aquatic food chain and ends up in freshwater fish people eat."

Sometimes the question is decided by someone else and we are hired to answer it using our scientific expertise. A mining company might hire you to answer the second question because you have the skills to execute that kind of scientific study.

After you have your question you design your study, you write a proposal, you execute the field work, you analyse the data, and you communicate your results.

What is a species?

This is a question that biologists have debated and continue to debate. There is no simple answer that all will agree upon. Nonetheless, we use "the species" as one of the most important metrics in field biology. The other important metric is "the individual" which we use to make population estimates. For many taxa[1] it is simple to distinguish individuals. We can tell one individual spider from another spider. But it is not always so easy. For example, a tree that shoots up a second trunk from a buried root might look like two individuals, but it is actually just one individual connected underground.

No one is really sure how many species exist. However, we do know that the vast majority of them exist in the tropical rainforest and coral reef environments. The relatively small land areas found in tropical nations like PNG are extremely rich in biodiversity. For example, a single hectare of rainforest on Crater Mountain in PNG has more tree species than all of the Appalachian Mountains of the eastern USA - an area larger than all of PNG! This biodiversity[2] is an asset and resource to be conserved for the future, just as fresh water or the air we breathe are resources needed for future generations to survive.

Estimates on how many species exist vary from low estimates of about 4 million to more extravagant estimates of 100 million! A lot of the variation in estimates depends on how one defines a species. Currently, somewhere around 1.4 million species are recognized by taxonomists (Table 3.1). Clearly, there are a great many more species to be described. Even if you went with the low estimate of 4 million, it would mean that in 300 years of naming species biologists have only described 35% of the species on Earth. There are still many, many unnamed species and most of these occur in the tropics. New Guinea is

[1] **Taxa** is a general term for a groups of species with a shared position in the "tree of life." Taxon is the singular of taxa. Birds are a taxon, mammals are a taxon; together they are taxa that could be lumped under the taxon "vertebrates." We use taxa and taxon when we are making general statements about groups of species or subspecies. People who study the classification of taxa are called taxonomists.

[2] **Biodiversity** is a general term for all living things-- all species and all individuals combined; or in other words all the taxa combined are called biodiversity.

one of the hotbeds of new species discoveries. The less diverse temperate regions have been more thoroughly studied. You, as biologists in a tropical nation, have a tremendous opportunity to broaden our knowledge of life on the planet by expanding our knowledge of the 2.6 to 98.6 million species which we are so ignorant of that we do not even have a name for them!

Table 3.1. Biodiversity of Papua New Guinea. PNG is richly endowed with biodiversity. For most major taxa PNG has more than four percent of the world's total biodiversity, in an area under one percent of the earth's land mass. More importantly, a high percentage of these species, often over 70%, are endemic to New Guinea (live nowhere else on Earth).

Taxa	Species in PNG (%)*	Species worldwide
Fungi	90,000 (9.0)	100,000,000
Vascular plants	20,000 (6.7)	300,000
Orchids	3,000 (12.0)	25,000
Butterflies	820 (4.5)	18,000
Fish	3,000 (9.5)	31,500
Birds	765 (7.8)	9800
Reptiles	220 (2.7)	8300
Frogs	280 (4.9)	5700
Mammals (non-marine)	210 (5.1)	4140

*Species estimates for most taxa are still approximations as many new species are being discovered or reclassified in the world, and particularly in PNG.

We use a binomial (two name) system to name species. The first name is the Genus. The genus[3] is a group of similar species that we hypothesize have a shared evolutionary history. Often detailed study shows several things in a genus do not share the same lineage, so they are then moved to different genera. This is why you will sometimes see the same species in two different genera. This means the two authors did not agree on how to group the species into genera. It is a healthy part of biology to improve and change classifications. It is important to be aware that these changes occur. So it is often important to refer to which authority you are using in your work. For example you could say "bird names follow Beehler et al. 1986."

The second name refers to the species. This is the basic unit of measuring biodiversity. These are the entities we intuitively group as having very similar DNA and which can freely interbreed. They look and act similar. Often different ethnic groups in PNG have classified species similarly. So there are words for many things we call "species" in their languages. It is important to also note that this classification is dynamic and can change with more study. Sometimes we discover that one seemingly fairly uniform species is actually two or more distinct species with very different DNA or different songs. E.g., many frog species are difficult to distinguish until they sing. Early collectors working with only dead specimens classified them as one species. Again, in nations like PNG where there has been less research, we are discovering more and more cases of such "hidden" or "cryptic" species.

Every species name we use, like the bird *Monarcha rubiensis,* or fig Ficus dammareopsis, refers to a type specimen (NOTE: scientific names are always either *italicized* or underlined with the first letter of the genus Capitalized and the species not capitalized). A type specimen is the specimen used as the defining individual used by the person who first described the species. Often the name of the person and/or the date they described the species follows the scientific name (e.g., *Rhinolophus euryotis* Temminck, 1835). Any time you use the name *Rhinolophus euryotis* you are saying that this individual you are talking about is the same species as the individual that was used by Temminck to describe the species back in 1835. It is important that you have a voucher specimen of your species (e.g., *Rhinolophus euryotis*) from the population you found it in. That way, if there is any doubt about the species identification you have made (and most species of most taxa are difficult to positively identify without a specimen), you can compare the specimen (and its DNA) to others that have already been carefully examined and identified. In important cases you can even go right to the source and compare your specimen to the type that defines the species, even back to a specimen more than 150 years old, as in this example. You

[3] NOTE: plural of genus is genera, not genuses (remember, you won't sound like a genius if you say genuses)

can see how important it is to properly prepare and curate your specimens-- folks in 150 years will still be using your specimens.

Species are defined by type specimens and identifications are made with specimens. Without specimens to back-up survey and inventory work, there can always be doubt about what you really identified. Without a specimen, future workers who read your reports can never be 100% certain your identifications are correct. There are many other reasons to collect specimens that we will not go into; however you should learn that it is necessary to collect voucher specimens from surveys, or any other field research. A good description of the value of collecting specimens and their many uses relevant to conservation is found in Remsen, 1995. This article deals with birds but is equally applicable to all kinds of plants or animals. Of course, you must make decisions about when not to collect-- vouchers should not be collected if it is illegal, prohibited by landowners, or if it threatens a population of a rare species. Vouchers should not be collected if you will not have time to properly prepare the specimen. But a fundamental first step for any beginning biologist is to learn how to properly prepare specimens. This will be an important part of your field instruction.

It helps to have reference materials on surveys to help identify what you see and capture. If you can be fairly sure of your species identification, then one or two vouchers might be sufficient to document its presence on your survey. Unfortunately, Papua New Guinea does not yet have good guides for many taxa – but this creates a wonderful opportunity for the determined student – you could create one! Here students use a guide to identify bats that was published by a former curator of the PNG National Museum and Art Gallery.

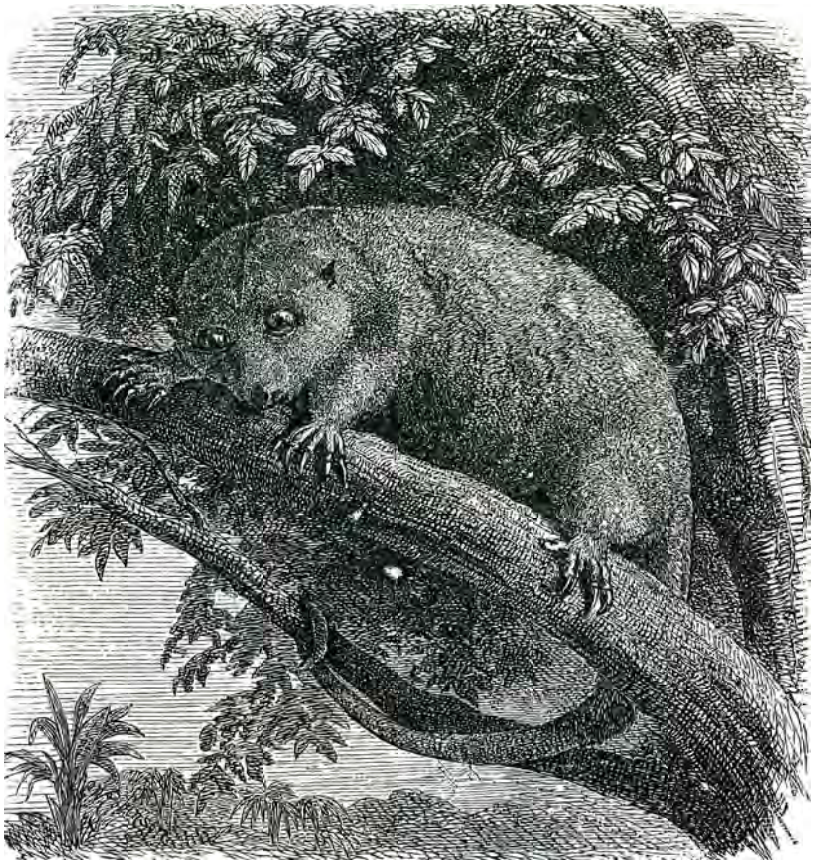
Field Biology and Conservation

The greatest immediate threats for species loss in PNG are resource development projects, unsustainable harvesting of forest plants and animals, and conversion of forest lands for agriculture. Climate change might have profound effects over a longer time span. Marine biodiversity is threatened by over-fishing, mangrove clearing, and poor water quality (Osborne 1995). Mining activities have resulted in fish kills and water pollution in some areas of PNG (Smith and Morris 1992) and an estimated 0.1-0.6% of the country's forests are felled each year (Saulei 1990). This rate is increasing (Osborne 1995). Wildlife is a key food resource for millions of rural people (Mack and West 2005). Where these activities occur different biological communities are affected. Yet our knowledge of the distribution of most biodiversity in PNG is so scant that we cannot predict what will be in any place or impacted by any activity. Thus surveys are the logical first step to assess the potential impacts of any activity, from population growth to open pit mining. We usually do surveys before developing a monitoring program. You have to know what you are going to monitor before you can begin.

Given the pressures for development, there is a tremendous need for biological information by the people who are trying to manage and conserve our natural resources. Further, given the evolutionary history of every community and species, solid information from any one place or taxon in PNG contributes significantly to our understanding of natural processes worldwide.

Field biology is needed to help guide conservation, but it is not the only thing needed. Social sciences, economics, and many other factors play a part in conservation. Biology is part of conservation, but being a biologist does not make you a conservationist. Nor does being a conservationist mean you are a biologist. Conservation almost always requires teams of people with different skill sets working together for a conservation goal. Conservation ultimately

means some group of people changing some behaviour. It might mean a logger only cuts certain trees, or a fisherman closes a reef to fishing for a couple of years. It might mean a politician enacts legislation to protect an endangered species. It might mean a customs official stops the export of Boelen's Pythons for the international pet trade. It might mean a landowner stops hunting Long-beaked Echidnas. These are the people ultimately making conservation happen and they are just as essential as the field biologist who might reveal the reasons these actions are needed.



CHAPTER 4: Basic skills

In this chapter we list some basic skills that apply to just about any field work you might do.

Record keeping

It is essential to keep a good written record of all data. One should never trust their memory for important details. All information you might want to use someday needs to be recorded. And, with so much recorded information collected over the years, it needs to be well-organized or you will waste huge amounts of time trying to access your own data. Before starting any project you need to give careful thought to how you will record data and how you will store it for future use.

Basic note-taking and record-keeping apply to almost any project you will do and should be standardized to keep yourself organized throughout your career. Often these notes will be used by other people, sometimes long after you have died, and so it is important to keep the same sort of information that other biologists would want to have access to. There are standard basic formats you can use and adapt to your personal needs.

You need to learn four main types of record keeping: ***a journal, a field catalogue, data sheets, and an expense ledger***. You will use these often in your career, so the sooner you start keeping them, the better.

Journals

A journal is a daily log of your activities, much like a diary, but with particular emphasis on biological observations. You make an entry for every day, and at a minimum you record the important details of each day. These include:

- date
- your name
- location-- an unambiguous location, preferably with a GPS fix for latitude and longitude, and elevation
- collaborators-- who you are doing the field work with
- habitat-- a description of the habitat
- If you are in a single location for a long period, you can give details on the first day you are there and then in subsequent entries refer to the earlier description, so you don't have to re-write the same thing many days (e.g., "Gahavisuka Provincial Park, as described on 9 June 2010").
- weather—record this as well as you can with your equipment (min/max temperature, rainfall, cloud cover)
- description of activities-- what you did each day and with whom
- important biological observations, particularly those that do not appear in your data sheets
- periodic summaries of field observations
- cross references to data in other locations (e.g. data sheets or catalogues)

A sample daily journal entry:

> 15 June 2010, Andy Mack. Gahavasuka Provincial Park, EHP (06 °00'53'' S, 145° 24'45''E) 2400 m asl. Mid montane forest as described in detail on 13 April 2010. Overcast all day, temp 15-29 C,

light mist in the early morning, heavy rain at 1600h. Conducted mist-netting surveys with Paul Igag and Banak Gamui. Opened 15 12m nets along the main trail at 0600 and tended them for birds until closing at 1530 prior to heavy rain. 28 birds captured and banded, noted on data sheets.

Incidental observations: *Pteridophora albertisii* males singing at several places along the net lane. Several flowering trees attracted large flocks of lorikeets, mostly *Charmosyna papou*__and *Trichoglossus haematodus*. A local man was observed cutting wood inside the park and this was reported to the park guard. Many gingers are in flower now.

Summary observations: In the past five days of netting we heard Superb birds of paradise calling from at least three different locations around the parking lot. It is unclear if this is one or more individual.

Often at the end of a field session you should make summary observations before you leave a site-- noting the relative abundance or how many times you saw different species. After any survey or field trip you should immediately write up a detailed summary of observations and results, before you forget them. Your daily journal entries will help you do this.

Field catalogues

The field catalogue is where you record the data for any specimen you collect. Every specimen gets a unique number. The first specimen you collect in your career as a biologist is number one. You record your initials, last name and the number, e.g., ALMack 001) and so on until your last collection. Some bird collectors have prepared tens of thousands of specimens. Botanists have gone much higher! Insects are usually not recorded individually, but are recorded in "lots" or groups since insects can sometimes be collected in huge numbers. Each entry has your name and the number followed by the date, location, and pertinent information for the specimen. This data varies depending on the taxa and will be discussed more in the taxonomic sections. For example for a bird you might record the stomach contents of the specimen, which you would obviously not record for a plant. You record how the specimen was secured, notes on the type of specimen (e.g., skin, pressed plant, etc.). Your best guess at the species of the specimen (later in the museum the identities are confirmed, so it is often not crucial to get the identification perfect in the field).

A sample field catalogue entry for a bird would read something like:

> ALMack 2782. *Melanocharis nigra.* 12 April 2008. Gahavasuka Provincial Park, Eastern Highlands Province. 06 °00'53'' S, 145° 24'45''E, 2050 m a.s.l., mid-montane *Nothogfagus* forest. Mass 13g; bill black, paler toward base; iris dark brown; legs blue-gray; netted in the understory; light fat; skull 50% ossified; light body molt; stomach has *Ficus* seeds; male with enlarged testes 8X 3 mm. Heart, muscle and liver tissues in EtOH. Dried skin preserved.

It is very important to keep numbering consistently and to never repeat numbers. When there are multiple samples (e.g., several plant vouchers from a single plant, or several tissue vials plus skin and skull from a single animal) they all should have the same number on them because they came from the same individual specimen on the same date. Each number refers back to the catalogue information for that individual on that date. However, e.g., if you go back to a tree and collect a voucher from it on a different date, it will get a new catalogue number because the information is not the same (the date is not the same). Often a specimen, like a tissue or plant voucher, will have only the collector's

initials/number recorded with it. Back at the museum the curators and their staff will take the information from your catalogue and link it to that specimen. If you lose your catalogue or your tags come off specimens, both the catalogue and the specimens become essentially worthless. Do not let this happen!

Data sheets

Data sheets are frequently used to record information for various survey and field research activities. To make the information meaningful and comparable you need to repeatedly sample the same standardized information from each individual. It is extremely helpful to have pre-prepared data sheets to help you make repeated measurements so you do not forget any of them. For example, an ornithologist usually measures the wing chord, leg length, bill length, and the weight of every bird captured. These measurements, along with additional information such as plumage condition, location of capture and band number, are recorded on data sheets. When used properly, data sheets remind a biologist of the measurements that are to be made, and they keep those measurements organized, thereby facilitating data entry, storage, analysis and distribution. ***You should use data sheets whenever you will be repeating a similar set of measurements or observations.***

All data sheets should be labeled with: 1) the name of the observer, 2) the time observations started and finished 3) a description of the location, including coordinates and habitat, and most importantly 4) the date of the observation. Data sheets should have a place to record each measurement that you wish to make as well as an extra place in which observers can record information or comments that do not fit into any of the categories on the sheet. See data sheet examples in Appendix 1. If you carefully plan your data sheets before you begin data collection, you will find your fieldwork goes much more smoothly. When you are ready to compile and analyse your data, or enter it into the computer, you will be especially glad you used a data sheet. Data recorded in straight longhand in a book is extremely difficult to organize and analyse. ***Always keep your data as organized as possible.***

It is vital that you store your data in such a way that it cannot be lost. The data represents that much time of your life-- if you lose 2 days of data you have thrown away two days of your life! Keep your data organized and neatly filed. Do not leave it lying around where someone might take the paper and use it for something else (like lighting a fire!). Never leave your data unguarded, like in a briefcase in a car, because someone might steal it thinking it is something else. Whenever possible make photocopies of your data and store these in a different place (like one copy at home, the originals in your office). Many people have not done this, then deeply regretted it when their office burned or their notebooks were stolen. Not only does this protect you from almost all crises (unless you should be so unlucky that your office and house both burnt down!), but it should also give you greater peace of mind. Your data represent a lot of time and effort; you will worry about it if you know it is not safe. If your data is not photocopied, you need to hand carry it on planes – don't put it in checked luggage that could be lost. If a porter is carrying it, keep your eye on that porter – don't let him/her cross a raging river that could wash it away forever. Copy it and keep each copy in a different place to be safe!

Expense ledger

It always makes good sense to keep a record of expenditures when doing field work. A simple notebook with a line entry for every expenditure, with the date, the amount, who you purchased it from, what it was for, and a cross reference to a receipt that you keep in a separate envelope is what you minimally need. It is a good idea to note where the money came from if you are possibly spending funds from multiple sources. A sample expense ledger might read:

> 15 March 2009; AL Mack; K17.50; Steamships Hardware; rope for holding

nets up; cash advance from Mama Graun grant.

16 March 2009; AL Mack; K26.50; Simon Biglotale; for field assistance cutting net poles; cash advance from research grant.

Again, a data sheet for expenditure entries is a good idea and is the easiest way to ensure you keep a good record. Make an entry every time you make a payment and endeavour to get a receipt for every transaction, whether you are buying goods from a shop or paying a field assistant in a camp. By using a ledger like this, you can easily enter your information into a spreadsheet. Once you do this, it is simple to produce high quality accounting as required by almost all donors and organizations. It also allows you to analyse your expenditures just as you analyse your data. This will help you plan future budgets.

Good record keeping habits

A common mistake of young scientists and even very experienced ones is poor record-keeping and note-taking. When we record notes or observations we know what we are writing. However, very often we come back to those notes days, months or years later and the events are no longer clear in our minds. Or even if we can understand our notes, they might be read by another person. I have had to throw out all the work of field assistants because of their failure to take good notes. I have had to throw out my own data at times because my notes were imprecise. If your experiment calls for ten replicates, but on two of those replicates your data is unclear, the whole experiment might need to be tossed out and you have wasted days, weeks or months of effort. You might as well take the few extra seconds to make good notes, or not bother doing the work at all. Below are some common note-taking errors. The instructors of this course have made all of these errors at some time and have suffered because of it, and we have had assistants who have made these mistakes who we made sure suffered too!

Dates: Every page and every sheet of paper should have the date on it. If you have piles of data sheets from several days and they become mixed up, you need to be able to put them back together. Do not just date the first sheet of a series. Never, Never, ***NEVER*** write your dates as "6/7/99." Some people put the day first, some put the month first. Some people do both interchangeably. You simply cannot tell what the writer meant and you might not remember what you meant in your own notes years later. Always, always, ***ALWAYS*** write the month out "7 June 1999" (or at least give a three letter abbreviation "7 Jun 1999"). This does not take much time and it can make the difference between your notes being data or being nothing more than scrap paper to light a fire with. If you have data on both sides of a paper, write the date on the front and the back. Later you might photocopy your data and then the copy of the back is a separate page with no date on it anywhere if you did not write it there.

Units: Whenever you make any sort of measurement, make sure the units are stated. If you record a temperature is it Centigrade or Fahrenheit? Grams or kilograms? Centimeters or millimeters? Many times the lack of units has caused researchers to discard data. On a good data sheet the top of each column states the unit. This way you do not have to write the unit every time you fill in a row. If you give the time use military time, "1306 h" or label AM or PM, "1:06 PM." Whenever possible use metric units, because they are the standard for scientists and ultimately are much easier to use (e.g., it is easier to convert kilometers to meters than miles to feet).

Penmanship: Take time to write legibly. You might be able to read your writing, but often we share our data and others might not be able to read what you wrote. Anytime you are not sure "is that is a one or a seven?" you have to throw out that data. It took time and money to get your data; if you throw it out because you cannot read

it you have wasted your time and someone else's money. We recommend that you "cross your sevens" so they don't look like ones: 7 instead of 7. Europeans and engineers do this.

Abbreviations: When you are writing notes quickly it can save time to use abbreviations, especially when you are making behavioral or timed observations. BUT, make sure your abbreviations are standard and clear. When the observation period is over, note on the bottom of the page what the abbreviations mean. The bird "Mm" might mean the Honeyeater *Melilestes megarhynchus* when you write it, but later on will you know it wasn't the Honeyeater *Meliphaga mimikae*? Remember, others might need to consult your notes someday, so even abbreviations you think are obvious might confuse your collaborators.

Signatures: Always put your name (or at least your initials) on datasheets and observations, especially when working in a team. Later on if someone in the team has a question about the data, they know whom to ask. Sometimes people on a team do things differently (like one measured in mm and another in cm) and having all data properly attributed helps clarify methodological differences. You work hard for your data, make sure anyone reading it knows who collected it!

Data transcription and entry: It is good to get in the habit of transcribing your data as soon as possible and entering it in a computer file if possible. Usually if you work by day you have time in the evening to transcribe your day's data in a summary format; maybe on a new, summary datasheet. Doing this enables you to immediate spot potential problems and solve them while the day is fresh in your mind-- was that "Mm" a *Melilestes* or a *Meliphaga*? It helps you keep track of your data and arrange priorities for the next day(s). "Have I reached my sample size of 100 yet?" By having a transcribed set of data back at the camp or base you also have an instant back-up in case you lose your field book one day. If you are going to enter your data in a computer you either want your original data sheet to use the same format you'll use in entry, or you should transcribe the data in the field into a format that is easily entered once you are at a computer.

When entering data in a computer it is best to enter it two times independently. You can then use the computer to identify entries that are not identical in the two versions. This is the best way to locate data entry errors, like typographical errors (this is how a spell checker works, only it already has one set of entries in memory). If you cannot enter it twice, get someone else to proofread the entered data for you after you have proofread it. Remember it is impossible to avoid typographical and transcription errors. Everyone makes them, typically at a rate of 2-3%. This is simply a fact of life. You can go back and catch most of them, but if you do not, you can count on 2-3 out of every 100 numbers you entered having some sort of mistake. You need to proof your data entry.

Financial record-keeping: If you are on a grant, contract, or employed by any sort of agency it will be necessary to keep good financial records while doing research. Donors, sponsors and employers usually want a full accounting of how all funds were spent. ***It is in your best interest to always keep good financial records (even though it might seem tedious)!!*** Try to get a receipt for every expenditure. If you are buying from someone who cannot write you should make out the receipt, but then get them to sign it, or put their fingerprint on it. Make sure the receipt is well labeled (e.g. someone might give you a receipt with just the amount on it, make sure it also has a date, what it was for, and who you bought it from-- you can write this on yourself). Keep an envelope and store all receipts in it. At the end of the project you will be able to fully account for your budget if you do this as you go. If you do not keep good records daily, it will be almost impossible to make a proper accounting. If you cannot do this and you do not have proper receipts, many employers and sponsors will suspect you have used money for unacceptable purposes. It is an unfortunate fact that there are corrupt people who will abuse research funds.

The only way employers and sponsors can spot such people is to assume anyone without proper accounts is corrupt. Even if you are not corrupt, people will *assume* you are if you consistently fail to keep proper accounts.

Financial records also benefit you. Records from earlier research will help you know how much money you need to continue a project or to start a new project. When you write a budget for a grant proposal you use your past financial records to obtain a valid proposal budget. Good records help you keep your personal money separate from professional expenses. You do not want to end up using your personal funds to subsidize something your grant or employer is supposed to cover. As with your data, the sooner you can organize your financial records on a transcribed data sheet or computer file, the better off you will be.

Mapping Skills

Any student is at least slightly familiar with maps. But mapping and interpreting maps (cartography) is a science in and of itself. You will undoubtedly need to improve your mapping skills as a field biologist. Almost all questions and studies in ecology boil down to changes in space and time-- spatial and temporal variables. Maps are diagrams of spatial relationships, so maps are fundamental to ecology. Biogeography is the study of the distribution of life-- requiring mapping. Land management and protected areas require mapping to delineate where different forms of management occurs. Every landowner in PNG has at least a mental map of their land. Political boundaries define who votes where and which magistrates serve which communities. A mental map is what you follow every time you set off with an objective that is out of sight, like walking from your dormitory to the science building. Maps are important!

In your fieldwork you will need to know how to read maps and how to make your own maps. You might read a map to get to a survey location. But once you are there you might need to map your trap locations, or the positions of trees on a study plot, or even the position of captured flies in a large spider web. Once you really understand how to read different kinds of maps[4], you will be better able to start making your own.

Common features of most maps

Every map should have a Legend. Even maps you hand draw in your notebook. The legend describes what the map is of (e.g., a Province or your study area). It should say who made the map, when and from what sources, it should have a scale for distance, and definitions of what various markings mean.

The map is a depiction on paper (or now computer screens) of another place. Usually the place is much larger than the map, so a scale is used to explain how the linear distance on the map relates to the linear distance at the place. For example some maps have a scale of 1cm = 1 km. This means if you measure a distance between two points on the paper that is 4 centimeters, then the actual distance between those points is 4 km. Scales are often written as unitless ratios. In this example it would be 1:100,000 because a kilometer is 100,000 centimeters. A unitless ratio then works for whatever unit you choose. For example one inch on the map would be 100,000 inches at the real place. The ratio is good because if you photocopied a map and either enlarged or reduced it, then the ratio of 1 cm being a kilometer would change. But if it is a unitless ratio, it does not matter how you enlarge or reduce the map (for example zooming on a computerized map).

Most maps have symbols on them. They might be a blue line for rivers, or a black square

[4] some kinds of maps include: nautical charts: showing water depth, navigational aids, shipping hazards, etc.; aeronautical: showing topography, major features visible from the air; topographic: showing details of elevation of the land surface using contours; geological: showing geologic formations beneath the earth surface; physical: showing features like roads, schools, buildings, etc.; demographic: showing population density in differently coloured contours. Any of these and many more could prove useful for field biologists.

for a building. A map should have a key that explains what each symbol represents. If you draw your own map, such as a map of where your traps are, you need to include a key to the symbols you use. You might understand that an "X" marks a trap location. But in ten years when you look at that map again, you might not remember and think that map showed the location of cuscus dens or something else you have mapped at some time. Without a key to symbols your map is not much use to anyone.

Many maps have a grid superimposed over them. This usually presents some co-ordinate system for mapping. Latitude and Longitude are the co-ordinate system most of us are familiar with, and the grid on a map could represent these parallels and meridians. But there are other systems, like UTM (Universe Transverse Mercator), where the grid is some unit of meters.

The compass rose for a map of the earth surface shows how the map orients to north. Often the top of a map is north, a standard and tradition with no particular reason other than early map makers were from the northern hemisphere. There are two measures of north: true north and magnetic north. True north would be where the north pole is located. It is a single consistent standard all mapmakers can use. But it is hard to determine true north directly. Magnetic north represents the magnetic fields of the planet that align close to true north. You can use a compass to detect magnetic north, so it is easier to use in the field. The difference between magnetic north and true north is called "declination." It is usually several degrees and it varies depending upon where you are on the planet, being greater as you approach the poles. Most good maps will have a diagram of a compass that shows true and magnetic north. You can use this rose to orient your map. When you are making a map of your own, particularly maps of relatively small areas, the error caused by declination is usually not enough to worry about. But if you are working with large distances it can be crucial. For example if you are navigating in a boat to a small island far over the horizon and you are using a map and compass to find the island, you could completely miss the island if you did not correct for declination. This is more a matter for navigation of ships and planes, and less concern in a study area of a few km.

Topographic maps

These are among the most commonly used and important maps for field biologists in PNG. A good series is available for very reasonable costs from the PNG national mapping bureau in Waigani. You can also obtain superb topographic information from digital online sources.

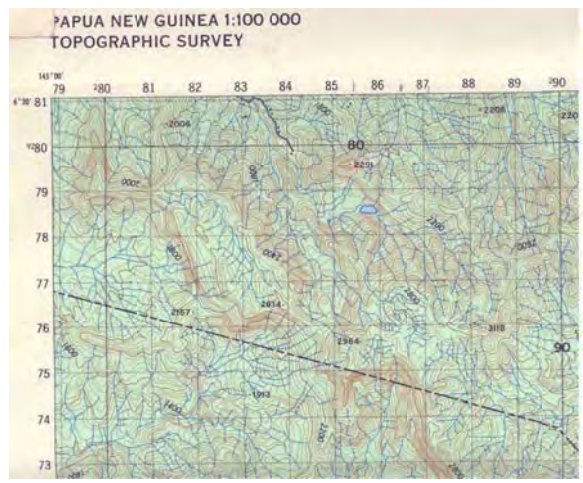


Figure 4.1. Example of topographic map.

Topographic maps show the relief of the land as contours. In the legend it will tell you the contour interval-- that is the change in elevation between two contours. In mountainous terrain like PNG, the contours are often 40m. This means if you walked from one contour to the next at that place on the earth you would change 40 in elevation. The closer together the contours, the steeper the land is and the further apart they are, the more level. Can you see where the cliffs are in Figure 4.1? Very useful information when planning a patrol or where to put a camp!

Standard topographic maps usually have quite a few other important physical features-- waterways, villages, roads, etc. Very few things can pack as much information into a single piece of paper as a good map! For example, with a map

you can measure the distance between any two points, of which there are an infinite number of pairs. You could not put all of this information into a table. Maps are an extremely data rich graphic. If you learn to use them effectively in your research, both to extract information and to communicate your results, you will be a much more effective field biologist.

Common Tools

Altimeters

Everyone who has moved from the lowlands to the highlands and tried to play sports knows that the air is "thinner" at higher elevations. There are fewer oxygen molecules for you to breathe. This is an effect of gravity-- air has mass and is "pulled" toward the center of the earth just as you are (otherwise we'd simply float like astronauts do) (actually space bends around massive bodies, but this isn't a physics manual). So this force ends up holding more air molecules closer to the center of the earth-- they become more densely packed or "thicker." As you move up in elevation, the air becomes "thinner." We can use tools that measure this difference in air pressure to tell us elevation above sea level. These devices are called altimeters. They can be pretty accurate. Traditionally pilots have used them to avoid mountaintops!

Air pressure also changes with different weather conditions. High pressure and low pressure fronts (large masses of air) move across the surface of the earth as a result of the different thermal properties of land, water, ice and other surfaces of the planet. These fronts can affect your altimeter and give a spurious indication of elevation change. For example, you can sit at the beach in Madang and watch your altimeter register a change in elevation as the barometric pressure drops in the afternoon. As if the beach rose 100 m in elevation as you sat there. This is why altimeters need to be calibrated often from known points. A good pilot calibrates the altimeter in the cockpit while on the airstrip where the elevation is precisely known.

Tape measures

The tape measure is one of the most useful tools you will use if doing any sort of ecology or standard sampling on a survey. For example, to be consistent you might want to put a trap every 100m, or lay out a plot that is 50 X 50 m. Using a tape measure enables you to accurately measure such distances. Pacing off such distances or other methods of estimating are inaccurate. Even though GPS units are very good for large distance measurements, they are not very good for precise distance measures less than 50 m. Expensive GPS units can be better at these small distances if you take several measurements over time and average them. But it is often much easier, faster and cheaper to just stretch out a tape measure between two trees to see how far apart they are. A key skill for the field biologist is to know which tool to use for fast, inexpensive and accurate data. Fancy gadgets that break are often no better than the old fashioned tool like a 50 m tape measure.

Compasses

Altimeters take advantage of the effects of gravity to help us orient ourselves. Compasses use the earth's magnetic field. The planet has a magnetic field oriented along the north-south axis from top to bottom. The magnetic field is not oriented exactly along the lines of the true north and true south poles (remember "declination"). But the magnetic orientation is close enough to help us. A compass is nothing more than a magnetic pointer that swings freely so it will orient with the subtle magnetic field all around us all the time.

A compass is an extremely useful tool in the field. It weighs almost nothing, but with it we can map the angles between points in our study area. And remember from basic trigonometry that if we know some angles and measures we can calculate other distances without having to directly measure them with a tape measure.

You will perform exercises in this field course so you become familiar with how to use a compass in order to map objects and to estimate distances between objects. Here are some

examples to help you remember how to use your compass.

To determine the angle (or "bearing") from you to an object: (e.g., what is the angle between a marked point on the trail and a trap you put in a tree away from that point on the trail)

1. Face the object or landmark you want a bearing for and hold the compass in front of you so you can sight accurately along it and also read and manipulate the bezel ring. Be sure to hold the compass level so the indicator arrow turns smoothly without touching the base and getting stuck. Check often to make sure the needle is floating freely as you work with a compass.

2. Point the large arrow on the base directly at the center of the target. Do not worry about the needle or bezel right now. Just line up the arrow on the base.

3. Unless your target is due north, the needle will be pointing in a different direction than the base is pointing. Grasp the bezel ring and turn it so the mark for north (0 degrees) aligns with the tip of the needle. Now you are done!

4. Now you can take the compass away from its level position and where it is pointing. Just read off the number on the bezel that aligns with the base arrow on the compass. This is the magnetic bearing in degrees to your target.

To determine which way to walk in order to move toward a specific compass bearing: (e.g., if you want to mark a transect that follows a specific bearing)

1. This is simply the reverse of taking a bearing (which we just explained above).

2. Without worrying about the position of the compass for now, turn the bezel so the bearing you want aligns with the marker for the arrow on the base of the compass.

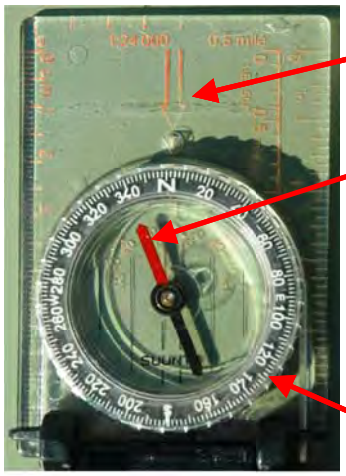
3. Now hold the compass in front of you and level so the needle turns freely and you can see the compass well.

4. Slowly turn your body holding the compass level and steady until the north needle aligns with the zero mark on the bezel. You are not turning the bezel—you have already set this where it needs to be so do not move it—you are turning the entire compass and your body.

5. When the tip of the needle is aligned with the bezel north zero, then your bearing is straight along the direction of the base arrow. If you are holding the compass in front of you at eye level, you can now sight along the axis of the base and pick out a point that is on your bearing, like a tree in the distance.

6. If you are making a straight transect you walk to that point, then repeat the process of find the next landmark along the transect, and then walk towards that. It is a good idea to flag or mark the transect as you go so you know where you came from.

There are different kinds of compasses, used in different ways; some are better for some



things and worse for others. A sighting compass is often more expensive than a bezel compass but is very easy to use. It does not have a bezel to turn and you do not look down on it; you put it up against your eye and look through a little opening. You will see the angle indicated by a vertical line sighting line. To get a bearing you line the sighting line of the compass up with the object you want the bearing for and look through the opening to read the angle. To move along a pre-determined bearing you look into the compass and move your body until you see the angle you want, then sight an object in the distance along the bearing as described above for the bezel compass. These are great for getting a

bearing, but they are harder to use with a map for orientation. You can lay a bezel compass directly on the map and orient with it.

GPS

Map, compass and altimeter use have limitations. It is hard to measure distances on the ground, compasses have a few degrees error in them, and altimeters fluctuate with the weather. Theoretically we could do all of our mapping needs with these tools, but it would be difficult and have a large amount of error. Luckily there is now a new tool that assists us by allowing us to make extremely accurate determinations of our position on the earth. We call this tool GPS, short for ***Global Positioning System.***

Maps, compasses, and altimeters are familiar to most of you and intuitively sensible. However, the GPS is a bit like voodoo magic; it helps to study up a bit before setting out to use a GPS for orientation or mapping.

GPS uses computer technology, fancy electronics, and a series of 24 satellites orbiting the earth about 18,333 km above sea level. The satellites send out radio information stating their exact position above the earth and they send out a precise time signal (accurate to about 3 billionths of a second!). The hand held GPS unit receives these signals and does some fancy computerized calculations to determine your exact location.

How long a signal takes to reach you depends on just two things-- the speed of the radio waves and the distance you are from the satellite. The speed of radio waves is a constant that does not change; we know that variable. The handheld unit gets a signal sent by the satellite with a time stamp saying when that signal was sent. It compares that time to the instant it was received and calculates how long it took for the signal to travel from the satellite to the handheld unit—that gives us distance since we know the speed of the radio waves and the time it took for the waves to travel to our GPS unit. The GPS also receives a signal from the satellite saying exactly where the satellite was when it sent the signal. So the unit knows exactly how far away it is from a known point, the satellite's position at the time it sent the signal. If you knew where a person started, that they moved at 5 km/hour and moved for one hour across a flat plane, you could draw a circle of places they could be. With satellites, we are working in three dimensions so we end up with a sphere of where you could be in relation to that satellite.

The GPS unit measures the distances to several satellites. The unit thereby determines where the unit is by triangulating to different satellites, all of estimated distances away. If you know you are on the surface of the earth and you know you are a specific distance from each of three satellites above you, then there is just one place those three distances will intersect on the surface of the earth (Figure 4.2). With just three satellites, you can be pretty sure where you are and with a fourth satellite the unit can measure where you are to within a few meters, even with error factored in!

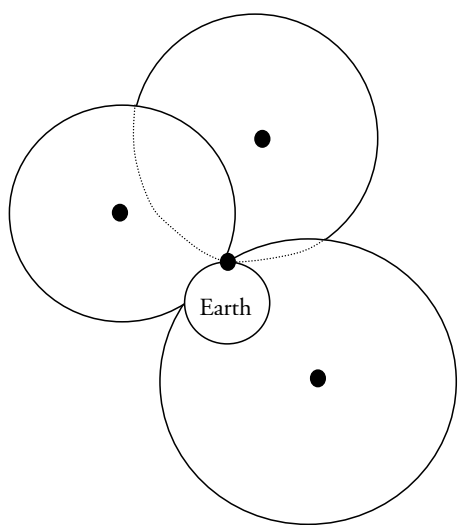


Figure 4.2. Known distances from three satellites yield just one point on the surface of the Earth.

Every GPS model is a little different. Each presents you with a user interface that you use to tell the unit what you want it to do and through which the GPS gives you the answers you seek. We will not go into the details of how to work with a GPS because the interface varies from model to model. But we want to give you a few basic concepts to help you before you start to

learn your particular GPS interface. On your field course you will have a lengthy set of exercises to make you competent with basic GPS use by a field biologist. A few important things to know are:

Waypoints: This is what the GPS calls a point that it locks into memory. You will create a waypoint for any important location during fieldwork-- say the location of your camp, the location of your trap, or the location of any point you either want to return to, measure, or communicate to someone else. You take a fix at the point and save it as a "waypoint." You can rename a waypoint anything you like (e.g., trap#1). Later you can export waypoints into a Geographical Information System (GIS) and it will accurately plot your waypoints on a map.

Tracks: Most GPS units will store position locations as you move and save them as a track. This is really handy, not only to find your way home after a long hike, but because you can map a track into your GIS map later. You can measure your track to learn how far you walked (without having to drag a tape measure all day).

Map Datum: The world is essentially a globe, but our maps are flat. This means we have to use some algorithms to create a flat map. Imagine peeling the skin off a round orange in such a way that it comes out a perfect rectangle. It is not easy to convert curved surfaces to flat-- there will always be some distortion. Depending on where on earth you are, there are different algorithms that cartographers use to correct for the distortion of making the round earth flat. These are called map datums. It is always ESSENTIAL to know what map datum you are using and include that in your notes. How your data will map in the GIS and how your distance calculations come out will be inconsistent (wrong) if you do not consistently use the same map datum. It is not obvious, but this is a crucial bit of what we call metadata.[5]

Transects, points and plots

Many kinds of field sampling start with one of three sampling methods and build on them. These three methods are: points, transects and plots. We use them to identify how and where we will take samples.

Points are, as suggested, single spots in your sample area. We might use a random number table or random number generator to give us points in a study area, representing a place in a delineated grid (random number for X position and random number for Y position), or along a trail or transect (random number for distance along that line). We go to those points and record some sort of data, like the depth of the leaf litter or percent canopy cover at that point. Points have no dimension (e.g., length and width), just a position in space.

Transects are one of the most commonly used methods of sampling in ecological studies. They can be applied in virtually any habitat, terrestrial, aquatic or marine. You can use transects to sample any two dimensional surface, such as a map, aerial photograph or satellite image. Once you understand the basics of sampling, standard sampling units, and replication, you can then design your own methods for your particular research question.

Transects are lines in the study area that you create. A transect has a linear dimension, like a 10m transect or a 10 km transect. The linear

[5] **metadata**-- this is data about the data. It is crucial in GIS – e.g., information about how you made your map. Were you using true north or magnetic north? What kind of GPS did you use? What was the calculated error in your GPS? How many satellites did your GPS use for each fix? What map datum did it use? Etc. A lot of metadata is stored for you automatically by a good GPS, but you should learn how to save and interpret it. Without their metadata GIS models and databases can be almost completely useless-- like having a car but not the keys to start it.

dimension defines how long the sample transect is. You also need to define how you sampled along the transect. For example you might place a trap every 100m along a 10 km transect—you have sampled for mammals at each 100m point. You can sample just along your transect line, or you can give it some width as well, making it a belt transect. For example you might count all of the seedlings of a certain species within 50 cm of either side of the transect line. This would give you a $100m^2$ sample area with which to estimate density[6] (100 m long * 1 m wide = $100m^2$). Transects are usually straight lines and are selected randomly. We often use our compass to help us walk out and mark a transect. Depending on the kind of sampling along the transect and the terrain, you might not make your transect perfectly straight.

Plots are areas; they have usually two measures-- a length and a width, which are equal in a square plot. Sort of like a very fat belt transect (there may be overlap in what you call a belt transect or a plot—the terms can be interchangeable). Or you can have circular plots with a single radius. Circular plots can be a nuisance to measure in forests due to trees getting in the way of the tape measure as you swing it around a central point. But often in open country or other habitats a circular plot might be easier. The important thing with plots is to know their exact area and to repeat them accurately when doing replications.

To lay out a plot, you often use compass and tape measure to measure one side, turn 90 degrees to measure the second side, turn 90 degrees again for the third side, and 90 degrees should bring you back to your starting point. In rainforest, and especially with large plots, it is almost impossible to lay out the plot so well that you arrive precisely back at your starting point. But it is important to get the boundaries correct, because just a few degrees in error can mean a substantial change in area. Your density estimates will be far from correct. A trick to help you get your plots perfect is: Use your knowledge of the Pythagorean Theorem[7] to calculate what the diagonal (or hypotenuse) should be for your plot. If you measure the two diagonal measures correctly, you can determine which corner points are incorrect and how to move them so your plot is squared properly as a square or rectangle.

Sampling transects or plots can come in many forms, from many kilometers to a meter. The dimensions will depend upon the density of things you wish to sample and the sample size you need for your analyses.

It is very important to layout your transects or plots accurately and to record all data in an organized way. Often laying out the sampling units takes longer than the actual sampling.

You might sample all of the trees within 20 m of your central transect, or if you are sampling something small and numerous like grasses, you might only count them within ten centimeters of the center line.

Basic specimen skills

In later chapters of this manual we will describe specific techniques for preparing specimens of different taxa. There are certain aspects of collecting, however, that are true for anything you might be working with, whether it is a plant, a mammal, or a worm.

Sometimes you will need to prepare voucher specimens. This is true for biologists anywhere in the world, even in well-studied countries like the United States. In PNG it is particularly important for two reasons: 1) it is often necessary to use a specimen to determine accurate species identification (and almost certainly subspecies), and 2) the specimens collected as vouchers are essential research tools

[6] **density**- this is an important measure in field biology—it is simply the number of something (often individuals of a species) within a specified area.

for improving our understanding of PNG's biota. You voucher strengthens your study so that you have proof of your data and people do not have to simply rely on your word; this can be especially important for new biologists who have not yet honed their identification skills. Other scientists will use your specimens for their studies too (DNA, taxonomy revisions, etc.), and so by collecting vouchers you are helping other biologists, planners or ecologists.

However, before you collect a specimen you need to consider its rarity and if you will be doing more damage by collecting it than by not collecting it. In most cases you should not collect vouchers of protected or endangered species; only collect these if they appear to be something new to science. Further it can be quite controversial to collect vouchers in protected areas where landowners have been told that conservation is important. If you kill and collect a lot of animals this can seem hypocritical and send the wrong message. Of course if it looks like a new species or sub-species you may have to collect a voucher, but be careful to explain to the landowners why you are doing it.

Remember, when collecting any specimen or doing any work in PNG, first make sure you have the explicit permission of the proper landowners. It is important to explain how collecting is for science and study, and that specimens are never sold. Explain that you are not making any money from the specimens—that they will go into museums for the good of all mankind. It can be useful if your funding allows it to take landowners out to visit a museum so they can see for themselves what happens to the specimens; otherwise it is difficult to understand this concept.

You should know how many specimens you are capable of preparing in a day and make sure you do not collect more than you can prepare. This goes for all taxa, but is particularly true for animals that can begin to rot quickly. You might not have to process plants as quickly as animals. Keep careful records of what you collect so you can make good notes in your collecting catalogue (Foster and Cannell 1990).

Labeling specimens

A specimen, no matter how well prepared, is almost useless without a proper label. You should always take particular care to attach labels that are complete and correct and will not fall off. The more data on a label, the more valuable the specimen becomes. Many museum specimens were collected long ago when people did not put much information on their labels. These specimens are of little use to science – in some cases we don't even know where they were found. ***Do not make the mistake of preparing a specimen with a poor label***-- if you do you are just wasting your time. Sometimes we tag a specimen with a catalogue number and record all of the label data in a catalogue with the specimen number. A good description for labelling bird specimens is found in Foster and Cannell, 1990; much of this applies to other taxa, but each taxa has special data that should be collected for it. For example, you should measure the length of the ear on mammals, but you will have a hard time doing this with birds!!

Whatever you are studying, collecting, or surveying, you should at least have the following information on your label:

Location: Give the name of the place if it has one, but do not ONLY give a local name. You should accurately describe the location, referring to landmarks that will be on most maps. Always refer to the nearest named place that will be on most maps in addition to the place name if that is obscure (like a small village name, or tok ples name), (e.g. 12 km northwest of Goroka Airstrip, 1 km southeast of the crest of Mt. Wilhelm). You should give the latitude and longitude of the location. Give the altitude of the location. Use metric units for distance measurements. Bear in mind that in the lifetime of a specimen, the names of places are likely to change. Many older specimens are from "British New Guinea." Without latitude and longitude

many place names will not be known in 100 years.

Date: It is best to write out the month when you record the date. DO NOT USE NUMBERS FOR MONTHS. Someone in 20 years is not going to know for certain if "5/10/96" means the fifth of October or the tenth of May. Remember, your specimens, if properly prepared, will be used by scientists for hundreds of years, long after you have died!

Collector and Catalogue number: Every label should carry the name of the collector and a number that refers to the collector's catalogue. In the catalogue you write all the data that appears on the label. This way there is a second record of the label data. Catalogues are very useful records of scientific data. You use the catalogue number to relate multiple specimens, like a flower preserved in alcohol with the pressed leaves from the same plant; or a bird skin with the tissue sample collected from the same individual (all the separate specimens from a single individual should receive the same catalogue number).

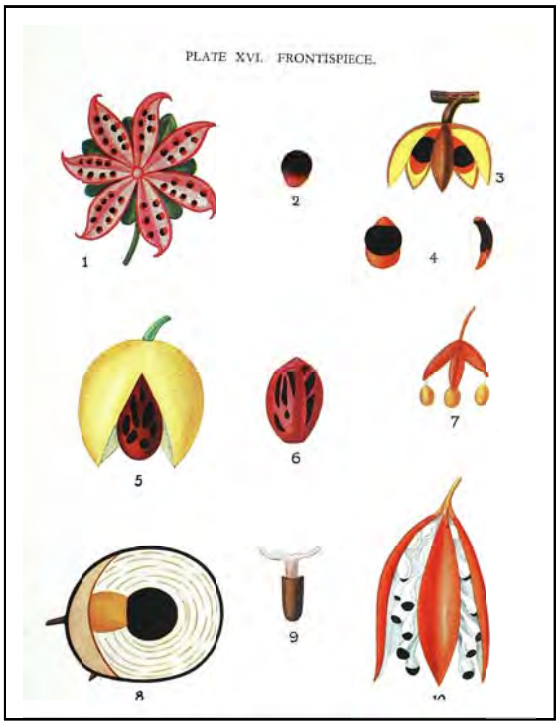
Habitat description: You should describe the habitat at the collecting locality. The more accurate the description the better our knowledge of the sorts of places this species occurs. For insects you might want to give the name of the species of plant you found it on, for fish you might want to describe how muddy the water was or how fast flowing. As you work with different kinds of organisms you will learn the kind of habitat information that is most useful. Be explicit, do not just describe a habitat as "forest," "river," or "swamp."

Sex: Whenever possible give the sex of the specimen. Often this requires dissection of the specimen as it is prepared. Do not base your attribution of sex on secondary sexual characters, such as colour. Examine the specimen's gonads and describe them.

Ink: Labels should be written in permanent ink that will not fade or in pencil. Many old specimens are now worthless because the ink on the labels faded or smeared and became illegible-- don't let this happen to your specimens. Write carefully and legibly. Do not make spelling errors and do not use any but widely accepted abbreviations. It is a good idea to cross your sevens (7). People a hundred years from now will think well of you and remember you if your specimens are still useful!

Other: Each taxon has its own specific requirements for proper tagging and data recording. We will cover these in later chapters. However, you should be familiar with these minimum requirements of any good specimen before you focus on a particular group of organisms.

CHAPTER 5: Plants



Plants are crucial for study in PNG's rainforest. Of course, what you survey or sample will depend upon the specific goals of a project. But, in many cases it is likely that information will need to be gathered on the vegetation of an area in addition to whatever else you are looking at. Plants are of special importance for many reasons:

- Plants are the foundation of the food chain in all terrestrial ecosystems. Plants capture energy from the sun and convert it into forms that other organisms can feed upon. Because many primary consumers have specific food plants, the community composition of plant-eating organisms, be they weevils or cassowaries, is largely dependent upon the food plants found at a site.
- Plants form the actual physical substrate in which other organisms live. Even those organisms that do not feed directly on plants (e.g., Harpy Eagles) require the actual physical structure of a forest to survive (e.g., for nest and roost sites).
- Plants affect the physical environment. The canopy of a rainforest blocks about 95% of the sunlight from reaching the forest floor. Thus the inside of a forest is cooler and damper than a clearing would be at the same location. Further, the chemistry of fallen plant material dictates the nutrients and chemical environment in which other plants take root and in which leaf litter arthropods live. Plant roots also prevent soil erosion.
- Many plants have specific environmental requirements for survival. Modest changes in soil chemistry, rainfall, temperature, or humidity can affect the survival of various plant species differently. Thus plants can serve as good indicators of environmental changes.
- Plants are immobile and often long-lived. You can tag populations of plants and expect to collect data on their growth and survivorship much more easily than with a tagged population of birds or frogs. You don't have to worry about plants flying out of your study area. Such growth and survivorship data are indicators of environmental change in an area, and thus very important for monitoring purposes.

State of our knowledge

Tropical rainforest floras are extremely diverse and PNG is no exception. Although estimates of floral diversity in PNG run to 20,000 species, most areas of PNG have not been botanically surveyed and so precise species richness is unknown and likely to be much higher (Johns 1993). Local species endemism is expected to be great, but remains virtually unknown. There are 93 endemic plant genera recognized from PNG, but no endemic families (Johns 1993). PNG is widely recognized to have one of the world's greatest concentrations of floral diversity. Note that the most diverse families in New Guinea are widespread throughout the world. Nonetheless, although New Guinea comprises about 0.5% of the world's landmass, it holds 2-16 % of the world's species among widespread families (Table 5.1).

Table 5.1. The ten most diverse flowering plant families in New Guinea (from Hoft 1992) showing what percentage of the world's species are found in NG for those families.

Family	NG Species	World Species	%
Orchidaceae	2806	17500	16
Rubiaceae	838	10700	8
Poaceae	461	7950	6
Ericaceae	436	3350	13
Euphorbiaceae	426	7750	5
Arecaceae	314	2675	12
Myrtaceae	308	3850	8
Fabaceae	280	11300	2
Lauracae	278	2200	13
Cyperaceae	243	3600	7

Surveying Plants

Defining Strata

Forest vegetation is sometimes divided into various layers, or strata. There are five strata that are often recognized in rainforests: 1) emergent trees-- those that are taller than the main canopy, 2) canopy trees-- those that form the highest continuous layer of vegetation above the forest floor, 3) sub-canopy trees—those whose crowns are beneath the closed canopy layer, 4) shrubs—woody plants closer to the ground (1-4 m), and 5) the herb layer-- seedlings, and plants usually less than 1 m tall, often non-woody (Figure 5.1). In physiognomic surveys, these strata are sometimes portrayed in sketches of the vegetation along transects (e.g., Hyndman and Menzies 1990, Paijmans,1970, and van Valkenburg and Ketner 1994). They are usually supplemented with estimates of the ground area covered by each stratum, and by the average height of each stratum.

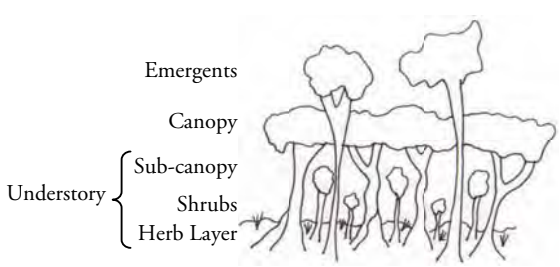


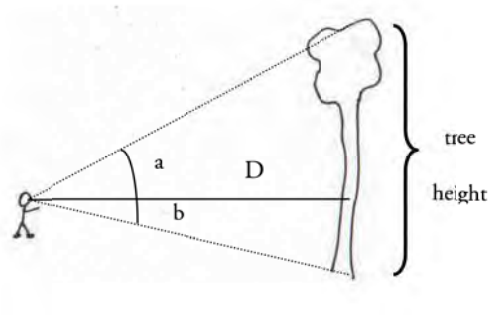
Figure 5.1. Plant strata.

However, strata are a set of labels ecologists use for convenience. It is often difficult to unambiguously assign particular plants to particular strata. Single individuals can occupy several strata over time, for instance the emergent tree that starts as a seedling, and then is a sapling, then an understory tree, etc. Other terms are also used, like understory for all plants below the canopy. Further, in New Guinea forests there is often not a single closed canopy, but instead a broken and uneven canopy. This is partly due to the especially dynamic nature of New Guinea forests; there is a high turnover rate in New Guinea forests due to landslides, storms and treefalls (Johns 1986). Because distinguishing strata is highly subjective we usually measure actual plant height in addition to or instead of recording strata.

Measuring Plant Height

It is easy to measure how high a seedling in the herb layer is, but it is much more difficult to measure the height of canopy trees. One easy way to estimate the height of a tree is to place a pole of a certain length (e.g., 3 m) against a tree, stand back and then count the number of poles you imagine stacking until they reach the top of the tree; then simply multiply.

Another method is to use a clinometer. This technique works by measuring the angle from the observer to the top of a tree and the angle to the bottom of it. When you then measure how far the observer is from the tree, you have sufficient information to trigonometrically calculate the height of the tree (Figure 5.2). To be accurate you need to stand at least the tree's height away, e.g., if you think it is a 50 m high tree you should stand more than 50 m away to get your angles. A measure of height is useful for describing forest strata objectively as well as for estimating the volume of trees on a plot.



D = distance from observer to tree
Tree height = D(tan angle a) + D(tan angle b)

Figure 5.2. How to measure tree height using a clinometer.

Measuring DBH and Tagging Trees

Plant Diameter at Breast Height (DBH) is measured with a DBH tape wrapped around a tree at 1.4 m above the ground. If you do not have a DBH tape you can calculate DBH by measuring the circumference of the tree with a regular tape measure and using the following formula: DBH = Circumference/π.

Because DBH is relatively easy to measure and less prone to estimation error than tree height, it is normally used as the main descriptive statistic for trees on forest plots. We use DBH to describe tree size, to calculate wood volumes, to calculate relative basal area of woody stems and to monitor growth and size-specific transition rates. It is often useful to measure DBH for all trees within a plot and produce a frequency histogram of different tree size categories (see Chapter 11); this gives you an illustration of tree sizes within the plot.

We usually use the standard of 1.4 m above ground to measure DBH because "breast height" varies by how tall you are. You are measuring the diameter of the trunk so you should not include epiphytes or climbers. Before taking the measurement clean epiphytes from the area to be measured and run the tape under climbers and lianas; do not cut them. If the tree is on a steep slope, stand on the uphill side and measure 1.4 m up the bole and measure there; do not stand on the downhill side of the tree. If the tree has flanges or a buttress that alter the DBH, you should measure diameter above the flanges and record how high above the ground you recorded the diameter. When tagging trees, ecologists usually place the tree tag a certain distance, often 10 cm, below where DBH is recorded. This is because a tree will swell around a nail, thereby altering the diameter. We use aluminium nails becausae they do not rust and although they are more costly than galvanized steel nails, they cause the tree to swell less.

Diameter at breast height (DBH) is a standard measure in forest ecology.

Cut a stick that is 1.4 m high to easily measure the place to take your DBH on each tree.

There are special DBH tape measures, but you can convert your measurement from a regular tape measure if you don't have one.

Working in a team makes the work go faster—one person uses the stick to show where to measure, a second measures the DBH, a third records the data and a forth will hammer the tag with the tree number in the tree. A good team can mark and measure hundreds of trees in a day.

Identifying these trees and collecting vouchers will take much, much longer in our species rich PNG forests!

Plant Density

A standard descriptive statistic for plant plots is the stem density (of a pre-defined size). You obtain this by counting all of the stems on a plot and dividing by the area of the plot. For example if you have 200 10 cm DBH trees on a 0.5 ha plot the stem density is 200 stems / 0.5 ha = 400 stems per ha. You can do this for all stems, for particular species or for size groups individually. Thus you can compare the density of two different species on the same plot, on different

plots, or even densities of differently-sized individuals on the same plot. There is a great deal that you can do with a relatively simple dataset-- a plot of a defined size, the trees identified to species (or genus, or family), their DBH values, and the number of stems in each of these taxonomic categories. Chapter 11 discusses some of these analyses in greater detail.

Sometimes it is impractical to set up a plot or transect. In such cases there are methods of "plotless sampling" biologists employ. We will not describe these in detail because it is best to make a plot or transect whenever possible. Also, some of these techniques work fairly well in low diversity temperate forests, but do not work as well in high diversity tropical rainforests like PNG. There are many sampling techniques, and some are more appropriate for some places or studies than others. It is important to research what particular techniques are best for your needs before you start a field project.

Survey Plots or Transects

Transects are long and narrow areas for sampling and plots (or quadrats) are less linear; otherwise they are essentially the same thing-- a delineated sample area of known shape and surface area. Transects and plots are sampling units used in all kinds of surveys, not just for plants. It is vital in all of your survey work that you use standardized sampling. If you do not have a standard unit, you will not be able to compare survey results from one location to another or from one point in time to another. And being able to make comparisons is a valuable way to answer questions (the comparative method).

If you have an adequate number of sampling units you will be able to generate species-area curves to see if your sampling is sufficient and to perform statistical tests to separate real effects from random effects. You will learn more about this in later chapters. You must give a great deal of thought to what sort of sampling unit you will use when setting up your studies. However, we can recommend a general plant survey sampling protocol that is useful and will yield results that can be compared with other studies in PNG.

First consider what you will be sampling—if you want to count the number of seedlings under 1 m tall your sampling area will be much smaller than if you want to count the number of trees over 10 cm DBH. Next consider the time and money available for your study—if you have little time you may not be able to do as many replicates plots. PNG forests are so diverse that if you are undertaking a floral survey to measure tree diversity we recommend you sample at least one hectare of forest. In areas with lower diversity (e.g. at very high elevations, or in highly disturbed areas) you might be able to sample smaller plot areas.

Setting up a hectare belt transect or plot

First we will describe setting up a one hectare belt transect. We recommend using a random number table to identify a point along a trail. Select a random number (say between 0 and 500 m) to be the distance from where you are (e.g., your campsite) to where you will begin your transect. You can use the random number table in Appendix 2. But make sure that your starting point will be in the habitat you wish to enumerate. For example, if you are staying in a village and the forest of interest is more than 1000 m away, you will not choose a random number between 0-500! Measure the random number of meters along the trail to your starting point. Now choose a random compass bearing from your random number table. Your transect will follow this bearing unless there are insurmountable obstacles, like a cliff; you can turn the transect if you reach a cliff, or stop it and begin it below the cliff—you just have to make a note of what you did in your methods. We are assuming you are making permanent transects-- you will want to do this unless you are absolutely certain the transect can never be revisited (e.g., a forest that is undoubtedly about to be completely clear-felled). It takes just a little bit of extra work to make a permanent plot, but the data you will obtain in years to come about growth rates, forest

turnover and species composition change will be extremely valuable. You want to always get the most from your hard labour in the field!

It is a good idea to start the transect at least 10 m from the trail, to reduce edge effects from the trail (e.g., people cutting vegetation along the trail). The transect bearing goes down the centre of the transect and the two edges of the transect run parallel (at the same bearing) 10 meters to each side. Thus the transect should be 500 meters long by 20 m wide, equivalent to one hectare.

Laying out the transect requires competence with a compass and teamwork. It is best if you can have two teams going down each side of the transect. At the beginning the two teams are 20 meters apart (each is 10 m from the centre line). The beginning corners should be permanently marked. We like to use PVC pipe cut into about 1 m lengths (PVC is good to use because it does not rot). These are driven into the ground and numbered with an aluminium tag tied with aluminium wire through a pre-drilled hole. For example, the first two corners could be numbered 1A and 1B, signifying the first sub-plot on the transect, sides A and B. The two teams then measure out 20 m with their tape measures straight along the same parallel compass bearing. When they go 20 meters they put in another two PVC stakes labeled 2A and 2B, to signify the beginning of sub-plot 2 (Figure 5.3).

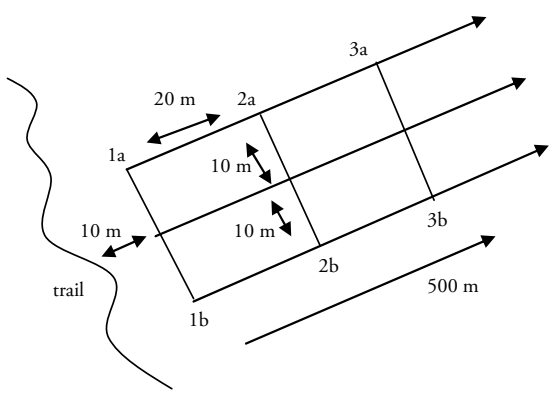


Figure 5.3. Laying out a hectare belt transect.

When you determine the corners of each subplot (e.g., points 2A and 2B) you must measure the distance between these two corners. They should be 20 m apart; you will need to re-do that sub-plot if they are not. As a further check for positioning the corners accurately, you can measure the diagonals: 1A to 2B and 2A to 1B should each be 28.28 m. If they are not, it means the two edges are not parallel and you need to re-do that sub-plot.

The teams continue until they have 25 square sub-plots that each measure 20 X 20 meters (20m X 20m X 25 sub-plots = 10,000 m^2 = 1 ha). The use of 25 sub-plots as standard sampling units will enable you to perform a number of statistical analyses we could not perform with a single one hectare transect. In other words we have a sample size of 25 rather than one!

Each team should sight back along their line (marked by the tape measure). Is the bearing correct all the way along the tape? Is the tape in a straight line all the way? If not, you should adjust the edge of the transect (by moving the tape measure and PVC corner markers) so that both lines are straight, parallel and 20 meters apart. This is hard at first, but with a little practice it becomes easier. If you do not correct your edges your data will not be accurate. For example, if your two teams are tracking a bearing just one degree off from each other, say 186° and 187°, by the end of the transect the end points will be 24.3 m apart rather than 20 m. You will have added an additional 545 m^2 to the transect, more than adding an entire sub-plot! It is important to correct any errors as you go.

Once your corners are properly positioned 20 m apart, it is good to go back along the tape measure and put flagging tape in the vegetation to mark the boundary of the transect. Flag the edge in such a way that it is obvious which trees are in the transect and which are outside. Once that is done, pull-in your tape measure, go to the beginning of sub-plot 2 and start out again on the same bearing. Repeat the process until you have your 25 sub-plots. This process will usually take two days, maybe more if the terrain is rough. But if you do a good job setting up the transect, it will

save you a lot of aggravation later, so do a good job!

If you reach an obstacle you need to make a decision. Your transect is meant to be a random sample of the forest, so natural features like tree falls should be included. However, if you come to a landslip in your third sub-plot that covers the next 20 sub-plots, it would not be desirable to include the landslip in the plot. The same is true for a big river. If you reach a major obstacle that is not representative of the vegetation you wish to sample (big river), or just plain dangerous (cliff), you can go back to your starting point and continue your transect in the opposite direction (skipping the 10 m before and after the trail so you still avoid that edge effect). To do this simply add or subtract 180° from your transect bearing. There are 360° in a complete circle, so you end up on the same bearing going the opposite direction if you change it by half of that, 180°. For example if your bearing was 187°, you would go back to your starting point and begin the transect going 7° in the opposite direction, skipping the area until you are 10 m on the other side of the trail. The important point is that you have a rule for how you handle barriers *before* you encounter them. You follow a pre-determined rule, like reverse the transect. Or you could decide to turn and use a new random compass bearing for the rest of the transect, or until the barrier ended, and then go back to the original bearing. Or you could decide to stop the transect and skip over the obstacle on the same bearing, and pick the transect up again after the obstacle. But what you cannot do is "decide" when you hit the barrier. This introduces potential bias. Decide ahead of time what you will do if you reach a barrier and stick to this.

Another standard is to make a square hectare plot. This is simply 100 m long by 100 m wide (10,000 m^2 is a hectare). Measure out 100 m, turn 90o and measure out another 100 m, etc. to make a square. If you are off you need to go back and correct. Make sure you measure your diagonals and they are 141.4 m. You can make your plot any shape you want; however, it is best to see what others have done before you so that your plot will be as comparable to the plots you want to compare them to as possible. If you make a 100 X 100 m square plot, or some other shape, you should still divide it into 25 20 X 20 m sub-plots to enhance your analysis options. Just mark these off within the plot, again using PVC pipes, aluminium labels and flagging tape to mark sub-plot boundaries.

The shape of your plot will also depend on your question. Do you want to see what the vegetation in a small area is (you might want a square plot), or do you want to get a representative sample of a very large area (the belt transect may be best).

Enumerating Plants

Now that you have your transect and sub-plots laid-out you can begin to collect data. It is a good idea to have your data sheets made-out and numbered aluminium tags ready to go. We like to number trees beginning with a T: T001, T002, T003, etc. This can be useful to separate trees from Lianas (L001, L002, etc.) or other items tagged and can help you discern numbers that might otherwise be read upside-down. For example a tag with 006 might seem like 900 if you read it upside-down, the "T" in front of the number prevents such mistakes.

You need to specify rules for what you are enumerating before you begin. A good standard is to record any tree that is ≥ 10 cm DBH. This is a standard cut-off point for most survey plots. If you enumerate smaller trees, it will take much longer and you would probably not need as large a sample size. E.g., if you wanted to measure trees ≥ 2.5 cm and ≤ 10 cm DBH in addition to the full sample of ≥ 10 cm in the hectare you might do this in a random 5 of the 25 subplots.

Tag each large tree or liana by nailing an aluminium tag into the plant. Although aluminium nails are more expensive than galvanized steel, they will not damage saw blades and will not react as adversely with plant tissue. Just drive the nail in part-way, so the tree has room to grow. If you drive the nail in too deeply,

in a few years some trees will have grown right over the tag and you will not be able to read the number. Do not nail the tag closer than 10 cm to where you measure the DBH because the plant will normally swell where you put the nail in, and this will give you an artificially high growth rate when you come back to re-measure. If you are marking small lianas, trees, shrubs and herbs tie the tag on with aluminium wire, but loosely enough to give the plant room to grow.

When you give a plant its number, record its height, DBH, and location within the plot using X-Y coordinates. For example if it is 9 m into subplot 2 and 14 m right, its location is X = 14 and Y = 29 (Figure 5.4). However, when you are in the field it will be easier to simply record the subplot it is in (subplot 2 in this case) and the X-Y coordinates within that subplot (X = 14, Y = 9). You can correct for the subplot when you are back at the computer.

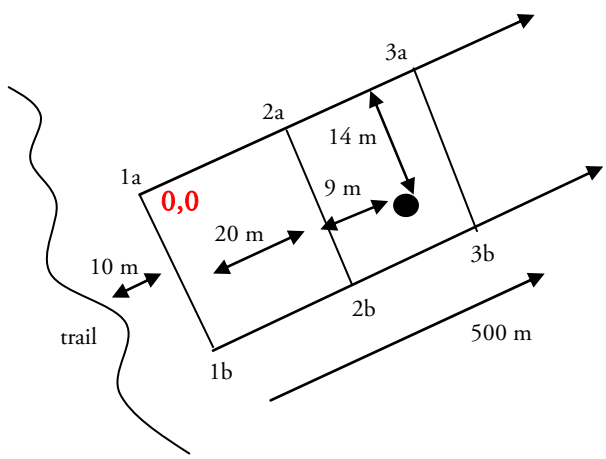


Figure 5.4. Identifying X-Y coordinate locations. The solid dot in this diagram is x = 14 and y = 29.

To record the sub-plot and location of your marked plant go by where the base of the tree is-- a tree that is rooted in one plot but leans over another or leans outside of the transect is still considered to be in the sub-plot where it is rooted; trees rooted outside the plot but leaning into it are not included.

When you are finished enumerating the plants on a standard survey plot you should have:

- One hectare divided into 25 20 X 20 m sub-plots, each permanently staked-out and flagged.
- All trees ≥ 10 cm DBH permanently tagged with a unique, unambiguous number (or some other standard cut-off measurement).
- All tagged trees measured for DBH and height.
- The location (sub-plot and X-Y coordinates within that subplot) for each tree recorded.

In addition, to be able to make intelligent hypotheses as to why your data shows what it does, you should map each subplot and draw a physiographic description for each: what are the slopes, where are the ravines, where are landslips or treefalls, rivers and streams, etc. This will greatly aid you in making sense of your data.

You have now quantified the plants in your plot and made a physiographic map; you can write a paper with just this data. You might want to go further and record plant species and biodiversity, but even if you do want to do this, it is usually more efficient to go through your plot and tag, measure and map all the trees first. Then you can go back through again to collect plant vouchers and identifying notes if you have time and funds, and your question requires it.

Identifying Plants

There is a tremendous diversity of plants in PNG; very few people can identify even most of the plants found at any particular site. The trick to learning to identify plants depends on learning what characters to look for. You should become familiar with the basic types of leaves (simple vs. compound), leaf shapes, leaf edges, etc. A very useful guide for learning techniques and characters for plant identification is Harrington and Durrell, 1957.

Once you have begun to learn the basic characters used in plant identification you can begin to associate which characters go with which plant family and then which go with each genus and species. It is a difficult, but rewarding task. A useful introduction to this is the field key made

specifically for use with PNG plants (Johns 1978).

To be certain of a plant's species name you need to collect a voucher specimen; that will allow others to verify your identification. You will need to know some basic plant characters in order to make proper plant collections, e.g., if the plant has compound leaves but you did not know it, you might collect several leaflets thinking you have a branch, but you are just collecting part of a single leaf. With a well-prepared specimen, most plants in PNG can be identified by someone, or can be given a new scientific name if it does not already have one. There are many new plants species in PNG to be discovered.

Recording Plant Data

A plant specimen (or voucher) is a whole plant, or parts of it, that have been compressed and dried in a press (you do this part), and then glued to a sheet of special paper that measures 43 x 28 cm (the herbarium does that part). Ideally, the specimen should display the characters of both leaves and flowers or fruits. These are called fertile specimens. If the specimen consists of only leaves it is called a sterile specimen. Flowers and fruits are crucial to plant identification, so whenever possible collect fertile specimens. Sterile material is much less useful. Usually you collect 2-3 duplicate voucher specimens for each plant instead of just one, so they can be divided between different herbariums. That way if one herbarium burns down, all of your hard work will not be lost.

Every plant that is collected should be labelled in the field with a unique catalogue number; usually the collector's initials followed by the sequential number of the collection (re-read the field catalogue section of Chapter 4). If you collect another sample from a tagged individual at a later date (e.g., when it fruits), you should make a new catalogue entry with a new number. This number is used for the specimen's entry in the catalogue. In the catalogue you need to record all of the information that the specimen itself will not give (e.g., you can see the leaf shape from the voucher and so you do not necessarily need to record this information). Each catalogue entry should minimally include the following information—the information that cannot be found from the specimen itself:

Collection locality: As discussed previously in this manual, you need to record specifically where in PNG a specimen was collected so other investigators can find that precise spot exactly and easily. Locality information should include:

- ***Political division.*** Note from big to small: Country, State/Province, District, etc.
- ***Geographic location***. Brief directions on how to reach the collection site (e.g., 1.7 km at 220° from the north end of the Herowana airstrip in the Crater Mountain Wildlife Management Area). Make it accurate but brief.
- ***Habitat description***. Use a standard description (e.g., cloud forest, lowland rain forest, pre-montane moist forest, etc.). Because plants are sessile (meaning they are fixed in one spot unlike most animals), you can also provide greater detail about a collection locality. For example: was the plant on a ridgetop, by a streamside, in muddy soil, in well-drained soil? Maybe it was growing on top of a rock, in a lake, or on another plant. As you learn more about plants you will learn what sorts of details are most likely to be important.
- ***Latitude and longitude***. To the nearest minute, seconds if possible. This is crucial. Trails, airstrips, and villages may not be there 100 years from now.
- ***Elevation.*** Record in meters. Never leave this out.

Collector's name: This helps future workers and enables you to take credit for your hard work. Use first and middle initials with full surname.

Date of collection: This is always important. With plant specimens the collection date gives important information about the

plant's phenology (the seasonal behaviour of the plant, particularly in reference to its reproductive cycle). If your specimen has flowers, we know by the collecting date that on that day this species flowered. With extensive collections we begin to learn about the phenology and ecology of plants in PNG. Specimens are valuable for the information they provide about ecology, evolution, physiology, etc. beyond merely serving as vouchers.

Plant size: On your plots you will usually be measuring DBH and height. Include these data in your catalogue entry. For shrubs or herbaceous plants measure the length and width of the plant.

Habit and architecture: Record whether the plant is an herb, seedling, shrub, understory tree, canopy tree, emergent tree, liana (woody), vine (non-woody), epiphyte (from the latin *epi* = upon, and *phyte* = plant; these are plants that live upon other plants instead of being rooted in the ground), hemiepiphyte (*hemi* = half; these plants are half tree/half epiphyte; they are things like strangler figs that begin as epiphytes, but then grow roots down into the ground and become rooted trees), etc. Architecture refers to the shape and branching pattern of an individual. Does it have buttresses or stilt roots? Is it monopodial? Does it have "terminalia-type" branching? Etc. There are many useful characteristics like this that can help to identify your plant. Remember, other workers will only have your specimen, not the entire plant as you do. You need to describe the characters that can help them visualize the entire plant. With a little practice you will learn what characters and terms you should record.

Voucher Description: You should record if your specimen contains leaves, flowers, wood, bark, fruits in ethanol, etc. For a single catalogue number you might record: Collected 3 vouchers of dried fruiting branches with leaves, and 2 vials of fruits in ethanol. Record this so you and future workers know what is available for study.

Ephemeral characters: Be sure to note any characters that will change or will not be evident in the dried specimen such as the colour of fruits, flowers and leaves. Record measurements and draw pictures of fruits and flowers in your catalogue as they will look very different after they are dried and will shrink a great deal.

Bark characters: The colour and texture of tree bark are important characters to assist identification. Is the bark shaggy or smooth? bumpy or fissured? You will learn standard terms for properly describing bark. Probably no other field of science has so many special descriptive terms-- no matter what character of a plant you want to describe there is probably a single word that precisely defines the character. For example, there are dozens of words for what we might call "fuzzy." If you master the terms, you will become an expert. If you do not master the terminology you will never advance beyond the novice stage.

Slash characters: Slash refers to a cut made through the bark to the wood. Most importantly does the slash exhibit an exudate (a flow of sap, latex or resin)? Is it coloured, thick, viscous, opaque, watery, copious? Does it change colour after exposure? You should also describe the under bark and wood. Is it hard, fibrous, or granular? Does it have a honeycomb pattern? Remember to check if the slash has an odour-- some plants give away their identity by their distinctive scent (e.g., cinnamon, peppermint, vanilla).

Plant number: If you are collecting vouchers from a plot you need to record which voucher specimen goes with which tagged plant. It is imperative that the voucher specimen you collect comes from that specific individual. Even if you are absolutely certain that another tagged tree is the same species, ***you cannot use a voucher from one plant to identify/verify another tagged individual!!*** It is easy to make a mistake in judgment on plant identification in the field. Often there are characters that are only visible with a magnifying lens, or characters that are only on flowers or seeds, which separate two otherwise identical species. Even if two individuals are certainly the same species, do not use a voucher

from one to define the other. For example you can easily collect 3 duplicate vouchers for T234 and you do so. You come across T543 and it is very difficult to get a collection—you are tempted to use one of the branches from T234 and say it came from T543 because you are sure they are the same species. ***DO NOT DO IT!!!*** First, they might NOT be the same species upon closer inspection. Second, imagine a scientist someday studying genetic variation using your specimens—they will be amazed to find that T234 and T543 are actually clones of each other! Often it is tempting to "cheat" a little on this, especially if some individuals are very difficult to climb. ***DO NOT EVER RECORD FALSE DATA.*** (This is the First Commandment for biologists). You can make a note that you think two trees are the same species, that is fine and is encouraged, but never assume so and substitute specimens.

There are several references that can help you learn to collect, describe and identify plant specimens. We recommend (Womersley, 1976), (Harrington and Durrell, 1957), and (Bridson and Forman, 1992).

Data Sheets: Most collectors use data sheets to record field data, then copy and expand the field data in their catalogues once back at camp. The data sheets can then remain with the pressed specimens for use by the herbarium that will receive them. We cannot stress too much that ***the use of data sheets will make your field work much easier and much more accurate!!!.*** Before beginning any project, you should design the data sheets that will make the project more efficient and effective, then improve the data sheet as you try it out in the field. You should adhere to the same data sheet format throughout a project, sometimes even through your lifetime, so that all of the data you collect are comparable. For an example of a data sheet to use for collecting plants see Appendix 1. A copy of the data sheet can be kept with your specimens and used when the vouchers are mounted at the herbarium. You might consider spending a bit more and getting a waterproof book, or waterproof paper for your data sheets, since it often rains while out collecting.

Collecting Plant Vouchers

After recording the necessary data, you collect your specimen. With small plants this is easy and sometimes the entire plant is collected (unless, of course, you are collecting an individual that is part of a permanent study). With large plants it is more difficult. You might need to climb a tree, or send a climber up to get a branch. An extendible clipper pole can enable you to collect specimens without climbing. In the forests of PNG many trees are tangles of vines and epiphytes and the branches of different trees overlap. It is absolutely essential that you are sure the specimen you collect goes with the rest of your information—that is, with your numbered tree. This is often very difficult. If you collect the leaves of a vine and record it as being from a tree you will never figure out what is going on! Someone who is helping you identify your specimens could waste many hours trying to figure out what the specimen is. At worst, your credibility as a scientist will be damaged if you do this too often.

Often the combination of climbing and using a long clipper pole will allow the researcher to obtain a good voucher specimen. But climbing can be dangerous and should not be attempted by the untrained student. It is vital to make sure the specimen you collect is from the target tree. With lianas, epiphytes and overlapping tree canopies, it can be easy for the novice or incautious to make a mistake. Vouchers with flowers or fruit (fertile) are much more useful than those of just leaves (sterile).

Your specimen should minimally include several complete leaves still on the branch and a twig tip so you can see the typical placement of leaves (e.g., alternate, opposite, distichous, whorled) and the apical bud. Try to get material that has stipules, flowers, or fruits if possible. Try to avoid collecting damaged material (e.g. chewed-up by insects or wilted).

Immediately tag your specimen by tying a tag to it with your unique catalogue number recorded upon it, or at least the tree number if you are sampling a plot. Do not use ink that is not water proof. We often tie a piece of flagging tape around the specimen with the plant number written on it with a marker. Place the specimen in a plastic bag (like a large garbage bag). If tags are securely tied on, you can place more than one specimen in each bag. The plastic bags protect the specimens as you carry them through the forest and keep them moist. Bagged specimens should be prepared (pressed) as soon as possible. But they can wait a day or two if they are kept moist and cool. Specimens that wait too long begin to lose their leaves and all you end up with is a twig and some loose leaves: not a very useful specimen. Specimens with flowers should be prepared as soon as possible because many flowers wilt rapidly. Floral characters are usually the most important for positive identification; take good care of the flowers and press them so that their characters are evident (stamens, pistils, etc.).

To prepare dry specimens: Pressing plants is relatively simple. Cut a specimen from your field collection that is representative and which will fit in a folded page of newspaper. Lay the specimen out on one half of the opened paper. Write the specimen number on the newspaper in several places including the lower right corner of the page, or better still, tie a numbered tag right onto to the stem of the specimen (or do both). Arrange the specimen so important characters are readily seen, including a twig apex if possible. Arrange the specimen so some leaves have their undersides turned up and some down because there are different characters on each side of a leaf. Eventually the specimen will be glued to a sheet of heavy paper so you will not be able to turn it over to see the underside of a leaf. Be sure any reproductive structures are not concealed under leaves. Be sure the specimen is not sticking out beyond the edge of the newspaper. Fold the newspaper over to cover the specimen and gently push any bulges down to flatten the specimen.

It is a good idea to put another sheet of newspaper on the specimen with the crease closing the open side of the newspaper containing the specimen. That way it cannot fall out of the paper. You should make several duplicates of each specimen, with up to ten duplicates of good fertile material. Duplicates (all numbered identically) can be enclosed together in a sheet of newspaper. The enclosing sheets help prevent specimens from sliding out of their sheets and keep duplicates together so you only identify a specimen once.

If you have very large leaves you can cut them up and label the pieces in separate sheets. For example if my specimen ALMack1274 had huge leaves I might cut up the leaf so the piece with the stem and other leaf bases was labelled ALMack1274 (sheet 1 of 4). Then each successive piece of leaf would be labelled ALMack1274 (sheet 2 of 4), etc.

Place your specimens in a plant press, alternating every few sheets with a sheet of flat cardboard, corrugated metal and other sheets of dry newspaper. Then flatten all the specimens between the two panels of the press and tie the press closed. Place the press in a drying box standing on its end so the heat radiates up between the newspaper sheets. In humid PNG it is a good idea to keep an eye on your drying specimens. You want them to dry quickly. If they dry too slowly the specimens in the centre of the press wilt and the leaves fall off, or they could grow mold. You can help specimens dry more quickly by opening the press every few days and rotating central specimens to the outside. You should also exchange damp cardboards and unnumbered newspapers with dry replacements. The faster a specimen dries the better, but you do

not want the specimens to get too hot or they could be damaged. Once the specimens are dry and stiff they can be removed from the press and heat source. At this stage they are ready for mounting. But if you are still in the field, you should bundle them up in hard dry cardboard and plastic bags so you can transport them to the herbarium without damage.

To prepare wet specimens: Sometimes in the field it is impossible to dry specimens. A wet specimen can be prepared that can be dried later. Often on surveys we do not have the time or dry box necessary to make dry specimens. In such cases we make wet specimens and dry them within 6 weeks at another location (like back at the University). To do this we prepare the specimen just as before, however, you ***MUST*** make sure the specimens are labelled with ethanol-proof ink or pencil. Wet specimens do not require as many inter-leaving sheets of cardboard and do not use corrugated metal (the metal heats up and so helps the drying process). Once the specimens are secure in the plant press, soak the newspaper in 70% alcohol (ethanol, or surgical spirits). Then tightly wrap the press up in plastic. You do not want the alcohol to evaporate. Once the specimens have been pressed for a couple of days they will stay flat. You can take the plant press off and use it with new specimens, but you must keep the specimens moist with 70% ethanol, bundled up with string and cardboard to prevent bending, and wrapped in plastic and tape to keep them moist. Large fruits, if they have become unattached, can be dried separately in a paper bag with the same catalogue number or they can be preserved separately in ethanol.

Back at the herbarium you place the wet specimens in a plant press and put them in a drying box. When the specimens are dry and stiff they can be removed from the press and heat source and mounted.

Concluding remarks

We have very briefly outlined some of the major points to consider when surveying plants in PNG. With this information you can now set up a plot and collect the data and plants from it using these guidelines. The data you collect will not only tell you about the place you are surveying, but will also be comparable to data from other studies in PNG and so contribute to our overall knowledge of ecology in PNG. Help on how to analyse these data are presented in later chapters.

We cannot devote enough space to thoroughly describe every detail of vegetation surveys. However this should get you started. The only way to really learn is to undertake a survey with experienced biologists. Be sure to take careful notes in the field as you learn techniques so you will remember what you have learned and can use it when doing your own surveys later.

CHAPTER 6: Birds

Introduction

There are 708 bird species in PNG (Beehler et al. 1986), of which 76 are endemic (Beehler 1993). Birds are the most thoroughly known Class in the PNG fauna and because of this, the priorities for avian research in PNG differ somewhat from those for other groups. Beehler (1993) identifies four gaps in our knowledge of birds in PNG that should be addressed in order to develop conservation and management plans in PNG. These gaps are: 1) we do not fully know species distributions or general patterns in bird distribution, 2) we are still unable to estimate the population sizes of most bird species, 3) we do not know how these populations change - in size, or in composition over time, and 4) we do not know what the patterns of bird movement are within PNG. We add a fifth priority: 5) we do not know enough about the ecological requirements and relationships of birds in PNG. Surveys of the avian communities at a variety of sites in PNG, combined with monitoring and autecological (single species) studies at some of these sites will help us fill gaps in our understanding. Even data collected incidental to other field studies in PNG can help fill knowledge gaps (e.g., Mack and Wright 1996). Studies of PNG's birds have played an important role in developing the disciplines of ecology and evolution (e.g., Mayr 1963, Diamond 1973, Mayr and Diamond 1976), not just in relation to questions relative to New Guinea. Students of ornithology in PNG can continue to make noteworthy discoveries that will interest scientists worldwide.

Survey Methods

Methods commonly used to survey birds can be divided into five general categories: point counts, line transects, mapping, mist netting and general searching. We will briefly describe each then describe general skills.

The first thing you must determine before designing your field methods is: ***"What am I trying to find out?"*** There are different methods for different questions you might be asking, so it is pointless to look for the best method until you have explicitly stated your question! If you want to estimate the population size of a scrub-wren, then you might use a certain method that would differ from the best method to estimate the population size of Vulturine Parrots. And neither of those methods would work if you wanted to learn how many species occur in a 1000 ha forest. Different methods would be best if you wanted to know the home range of a Vulturine Parrot. There are almost as many methods as there are questions. The trick in field biology is to adapt your basic understanding of methodology to specific questions you have.

Point counts

On a point count the biologist stands in one place and records every individual bird seen or heard during a standard length of time. Usually, the biologist also estimates the distance to each bird as he or she records it. Based on these data, the

biologist calculates bird densities (Bibby et al. 1992, Blondel et al. 1981, Buckland 1987). Combining the species lists from all of the point counts in an area will give you a species list for that area. Point counts rely upon the following assumptions (Bibby et al. 1992):

- Birds do not approach the observer or flee.
- Birds are 100% detectable by the observer, at least at some distance interval.
- Birds do not move much during the count period.
- Birds behave independently of one another.
- Distance estimates are accurate.
- Birds are fully and correctly identified.

Point counts can be particularly good if you are interested in estimating the numbers or densities of a particular species or group of species. However in diverse tropical bird communities, it can be difficult to perform point counts on all species present, especially if you are estimating distances to each individual encountered. Doing so for the entire bird community requires a superb ability to quickly identify birds and to record the data accurately and quickly. As with so many census techniques, having pre-made, well-designed data sheets makes a huge difference. One of the secrets to doing point counts effectively is a good data sheet. Point counts are best for assessing densities of fairly common or conspicuous species. Thus, even if you have not mastered how to identify all the birds in a forest, you can still do point counts for certain species that you can easily identify. Estimating numbers of rare birds with point counts requires many replicated points because you probably want to have 40 or more encounters before you estimate population size. Beginning field workers should only use this method for common, conspicuous and easy-to-identify species.

A good design for point count surveys in PNG is to establish a trail or transect in your survey area with stations marked every 150 m apart. Starting at early dawn walk the transect stopping at all stations for at least 10 minutes where you record the species and individuals heard and seen. Record when you begin a point count and when you end it, and make sure to spend the same amount of time for each count, otherwise you will not have a standard sampling unit.

If you are estimating densities, you will need to estimate distances to each bird. If you simply want to determine relative abundance and compare different sites with the same method you may just record everything encountered. It is best if you can identify most species you see or hear; if you cannot identify something note it anyway and describe what you saw or heard.

Line transects

Line transects are another common method used to survey birds, and they consist of a biologist counting birds while walking a predetermined route. On a map of the transect the biologist records the species name and distance from the observer on a line perpendicular to the transect. Line transects are best done in large, open areas where habitat is relatively uniform. As with point counts, this method is best for estimating populations of target species and difficult to use if trying to survey all bird species present in a diverse avifauna. This method too requires the ability to identify everything encountered (unless you are limiting your survey to specific species). Routes should be determined randomly, unless such routes are impractical. Line transects rely on the following assumptions (Bibby et al. 1992):

- Birds on the route are all detected.
- Birds do not move before or after detection.
- Distances are estimated accurately.
- Individual birds are counted only once (see above—birds do not move).
- Individual birds are detected independently (not as members of a flock).
- Bias from observers, seasons and weather is understood and accounted for.

Mapping

For species that are territorial, and in areas where these species have distinct breeding seasons, territory mapping can be an effective way to

estimate populations and home range size. In this method, the biologist makes repeated morning searches of a designated area, or plot, in which there are territorial birds. By marking on a plot map the positions of all birds, especially those that are both seen and heard, a biologist can later estimate the number of territories present on the plot, and the number of breeding birds. Assumptions of territory mapping are (Bibby et al. 1992):

- The observer is good at finding and identifying birds.
- Records are plotted accurately.
- Observation visits are standardized with regard to time of day and year, weather, and speed of coverage.
- Birds live in pairs in fixed, discrete and non-overlapping ranges.
- There is a reasonable chance of detecting a territory holder.
- It helps to be able to recognize or identify individuals within the population (e.g., birds are marked).

This method is usually only appropriate when doing an intensive study of a particular species. It usually requires long periods in the same study area.

Mist-netting

Netting birds enables you to collect rigorous quantitative data on a subset of the birds in a survey area: those birds occurring in the understory close to the ground. In PNG this usually represents about one third of the birds in a forested area. Mist-netting will not give you a complete species list, but it does have other advantages: it enables you to collect some voucher specimens, it is easier to identify captured birds, nets can be treated as standard sampling units, and it is less subject to observer bias than purely observational techniques. This is an excellent technique for surveys in PNG by beginning ornithologists unfamiliar with field identification of many species. We discuss how to use mistnets in the following skills section.

General Searching

When you want to compile a complete species list for a survey site, you can use general searching. This requires that you are able to find and identify birds in their habitats. You need considerable skill to identify most bird vocalizations, identify birds from brief glimpses, find birds that are hidden or cryptic, and know the habits and behaviour of birds. It can take years to acquire these skills, but it is worth learning because there are only a handful of biologists qualified to survey birds in PNG. If you have these skills you will be in demand.

When trying to compile a list of all species present, the observer moves quietly through the forest recording every species encountered. Sometimes it is advantageous to sit quietly and hidden where a fruiting or flowering tree can be observed to see what species come to it. Other times waiting at an overlook will reveal lories, raptors and pigeons flying above the canopy. Moving along a river edge can reveal herons or shorebirds. It requires good overall knowledge of the avifauna to even begin to approach a comprehensive list of what occurs at any one site.

Often people combine general searching and mist-netting on a survey. Netting can often reveal a few species even an experienced observer would overlook. Moreover, it lends the opportunity to collect some vouchers, check for moult and breeding activity, and enable some simple standardized sampling of a subset of the avifauna.

The use of a tape recorder (or other digital recording device) with a playback speaker and a good microphone can help identify birds, particularly those whose songs the observer does not recognize. A recording can be made of a vocalizing bird if you get reasonably close and have a directional microphone. Once you have vocalizations recorded, you can play them back through a speaker. Often when the bird hears the playback and will respond aggressively and reveal itself. Birds often approach the observer and display, giving you a good chance to observe and identify the species. A recordings library and

playback can help you learn new bird songs and find hidden individuals. Recordings also constitute a good voucher of species presence as well as traditional specimens. You can share recordings with colleagues later who might be able to help you identify songs you do not recognize. A library of catalogued recordings can serve as a valuable form of verification of the presence of many species.

Every time you make a recording of a bird vocalization (or any other recording, like frogs) you should make a recording of your own voice fully describing the recording, just as you would label a traditional specimen. Remember, that recording could be cut and pasted to other media and locations in the years ahead, so a data label should be recorded to travel with it. You give your name, date, location, and describe the situation exactly, whether you saw the bird, how you identified it, whether it responded to playback, etc. A recording without the associated data is virtually useless for scientific endeavours.

Auditory and visual surveys will help you to identify as many species as possible. An ornithologist must spend considerable amounts of time searching for birds in the survey area before being confident that most species have been documented (Beehler et al. 1995).

Survey recommendations for PNG

We recommend that surveys in PNG utilize mist-netting to obtain solid, quantitative data, especially when novice ornithologists are at work. But general searching should be employed thoroughly as well to obtain as complete a bird list as possible. Point counts also yield good quantitative data, but are highly observer-dependent. They are recommended when the same observer is comparing several sites or estimating numbers of certain species. Mapping and line transects are also usually best applied if you are particularly interested in determining densities of a particular species. These techniques are very difficult to undertake when recording data for all species in a diverse rainforest environment. Whenever possible surveys should collect voucher specimens, including recordings of bird songs. General recordings of the birds singing at a survey site are valuable vouchers. Often other ornithologists can hear species in tapes that you might have missed. Properly prepared bird specimens, like all vertebrates, should be deposited at the PNG National Museum and Art Gallery and at least one other museum. It is always a good idea to make duplicate vouchers and deposit them at more than one museum, just as you always back up your data. You never know when or where disaster might strike. By backing up and duplicating your data (specimens are data), you are well insured against a catastrophic loss in the event of a disaster.

Important Skills for Avian Survey Work

Using binoculars

Birds are small, fast-moving, and often in the treetops so they are hard to see. Almost all birds in PNG have distinctive markings that, if seen, can unambiguously identify the species. Therefore, it is necessary to use binoculars. If you have not used binoculars before you will need some time to practice using them to become expert in their use. Often you do not have much time to see a bird before it flies so you must get a view of it quickly. Practice binocular use by standing in an open area and randomly choosing something you want to look at. Raise the binoculars and view the object and focus on it as quickly as you can. You focus by turning the centre focus knob between the two lens barrels. The focus rings on the eyepieces should stay set at "0" unless your eyes are not the same. If your eyes are different (e.g., you have glasses with a different prescription for the left and the right eye) you will need to adjust the eyepiece (ocular) focus. Keep practicing with objects different distances from you until you can automatically put the binoculars immediately on the subject you wish to view and bring it into focus instantly. If you do not have good binocular skills you will be frustrated in the forest, seeing birds with your bare eyes, but rarely seeing them through your

binoculars. You will almost always need the added power binoculars provide to see the subtle fieldmarks that allow you to identify a sighted bird to its proper species.

Visual identification of birds

Because one often has only a short look at a bird in the forest, it is good to learn what field marks to look for in advance. A field mark is any distinguishing character that helps identify a bird (for example the colour of the legs, the presence of a crest, a line of white spots on the wing, etc.). Study the field guide (Beehler et al. 1986) in your spare time so that you know what field marks are important for what species. First learn the general marks that identify groups of birds, like the general shape and bill structure of a parrot. This way you can quickly narrow the field from all possible birds to those that are parrots. Then you can look for the field marks that differentiate the species of parrots. If you know what to look for in advance you have a better chance of seeing the proper mark even during a brief glimpse of an individual. It is usually not possible to take in all the details about a bird's plumage, shape and behaviour in one look, so it is crucial to know what to look for in advance. You can do this by studying the field guide-- it will make your job much easier when you go into the field. When you record your field notes it is important to write down what field marks you observed for the birds you have seen, especially for any unusual or unexpected species.

Auditory identification of birds

Most birds make some sort of noise, from pleasant and complicated songs to harsh screams or grunts. Usually these noises are distinctive for each species and are field marks as good as any you can see. The advantage of vocalizations is that you can hear birds that are far away or out-of-sight behind vegetation. Thus, if you can tell birds by the sounds they make, you can learn much more about the birds found in any region than if you rely on sight alone. Learning songs is often more difficult than learning visual field marks. For example, it is comparatively easy to make a field guide with good pictures showing the field marks you can see. However, it is difficult to make a field guide for songs. It is good to write down in your field notes your own descriptions of songs when you learn what a species sounds like. The exercise of making a written description of songs will help you remember them and recognize them the next time you hear the same sound.

Recording bird songs with a recorder is an extremely useful field method (Parker 1991) and the price of digital recorders has become quite reasonable. If you record bird songs you then have a good voucher to verify the birds you heard. Furthermore, if you record a bird whose song you do not know, you can often attract that bird close to you by playing the song back. Territorial, singing birds will investigate a recording of their song thinking it is another bird infringing on their territory. When they do this it is often possible to get a good look at the bird.

Capture and Handling

It is often necessary to capture birds in order to study them. You can learn much more about the birds in an area if you capture them. For example, you might be able to tell if the birds are nesting because they get a naked patch on the belly (called a brood patch) that they use to incubate eggs. Other important things you can learn from captured birds are: plumage details difficult to observe, moult (the growth of new feathers), presence of parasites, diet from analysis of droppings while being held, condition (by looking for fat deposits, feather condition or simply the mass of the bird), etc. Capture of birds gives important data on the ecology of the bird. Because birds fly and many stay in the treetops, live-capture can be extremely difficult. To obtain examples of many birds in New Guinea you will need to hunt them, either with shotgun, or less preferably with bow and arrow (arrows often heavily damage a bird). Live-capture of birds is usually accomplished with mist nets or with traps (Bub 1991). Mist nets are the best general

method for capturing birds in New Guinea (Karr 1981a, Karr 1981b).

Mist nets are woven from very thin threads and they are difficult to see, especially when set in shady, windless conditions. Thus, netting in forests is very effective. Because the thin thread from which the nets are made is fragile, special care should be taken to ensure the nets do not become entangled in brush, or fouled by debris on the ground. Do not let a net touch the ground and keep all twigs and leaves out of nets. The important thing to remember when netting, especially if you are new to netting, is to be very patient and cautious. Nets are fragile and you must take care not to tear them. ***Try to never cut a mist net.*** Your training instructors will always help you if a net gets tangled; do not be afraid to ask for help.

Nets in forested areas are set in narrow net lanes that have been cleared of vegetation. You clear a net lane using your bush knife so that the net will not touch any vegetation. However, you cut only the barest minimum of vegetation; if you cut too much, the birds can see the net more easily and they will also be more aware that something has changed in their home range and be more cautious. With a little practice you will recognize good places for net lanes from places that are not good. Each end of a net is attached to a 2.5-3 m pole, and the poles are driven in the ground or anchored so that the net is stretched taut between them. Where the ground is hard and poles cannot be pushed in securely, the poles should be tied to neighbouring trees so that they cannot fall. The horizontal strings of the net should be tight so the net does not sag. The net poles should be perpendicular to the surface of the ground and parallel with each other. This way the folds (or pockets) in the net remain loose. Birds fly into the net and drop into the pockets where they become tangled. A net that is improperly stretched will not have loose pockets and thus will not catch birds—they will simply bounce back out.

Capture is stressful for birds, and can injure them, so mist nets should be checked for captives frequently to minimize the chance of injury. You will learn proper handling techniques for birds. Properly handled, mist-netting injures very few birds and enables them to be released completely unharmed. Taking a bird out of a net is a skill that must be learned through practice and cannot be taught from a book. However, we will list the basic procedure here so that you can use these notes to help you remember the steps to make it easier to learn when you take your first bird out of a net. Your instructors have taught many people how to take birds out of nets and know that it is difficult to learn. Basic steps for taking birds out of nets:

1. Birds are very sturdy creatures and can be handled firmly, but not roughly. It is important to keep a good grip on a captured bird so it cannot break loose and become more tangled or injure itself trying to escape. Hold the bird around the body so it cannot flap its wings. When necessary to hold the bird by the legs, grasp both legs (the entire thigh) close to the body. Do not hold birds by their wings, by the lower legs, or by the tail-- doing so will most likely cause injury to the bird. Whenever possible hold a bird with its back against the palm of your hand with the neck gently gripped between your index and middle fingers. This way you can control the bird, avoid being bitten, manipulate the net, and keep the bird free of injuries. The kinds of birds caught in mist nets generally cannot hurt you! Some can give a painful bite or squeeze with their claws, but this will not damage you, so remember to stay calm when a bird is trying to bite you. You would do the same if someone the size of a big tree grabbed you!

2. Figure out which side of the net the bird came in from. Generally you can tell by how the pocket of net around the bird hangs down. Some birds become very tangled and it will require practice to tell-- imagine the sequence the bird went through in order to get tangled the way it is-- you will want to run that procedure in reverse. The bird has to come out the way it came in-- a

bird cannot be taken through a net; only backed-out.

3. Grasp the bird from the side it came in and gently raise it up from the pocket. If a bird is not too tangled you can often grasp it well around the body and lift it out of the net. Often it will release the feet and you can ease the bird out of the net peeling the net off the wings and body as you go. But birds that have struggled a good deal and are more tangled do not lift out so easily and you have to work them free more methodically.

4. Disentangle the feet. First clear all mesh from the rear toe (called the halux). Once the rear toe is completely clear, you can gently free the rest of the leg. If the rear toe is not cleared, the rest of the net will not come off the feet.

5. When the feet and legs are completely clear (look closely to make sure there is no mesh up at the base of the thighs), grasp the bird by the base of the thighs, supporting and cupping the lower legs and feet so they don't become re-tangled. Pull the bird gently toward you and free any mesh from around the tail feathers.

6. Get a better grasp around the bird's body and peel the mesh completely off one wing and then off the other. It often is necessary to pull off as much net as you can with the wing bent, pulling net over the "elbow" and then with the wing open (extended).

7. When the wings are free you must be particularly careful to hold the bird around the body, as it can now fly away if you let it! Gently pull the mesh from off the back of the head toward the bill. If the tongue is tangled you must be extremely careful because there are prongs pointing backward (like on a fishhook) on the tongue upon which the net becomes caught.

Remember the bird flew into the net-- its beak hit first. Leading the whole head through the mesh up to the shoulders where the wings became tangled, then flight stopped and the bird dropped into the pocket and the rest of body became tangled. Once stuck in the pocket the bird struggled with its feet, making them very tangled. Taking the bird out simply reverses this sequence! The trick to getting a bird out of the net, is figuring out how it got into the net!! Reading these notes won't teach you how to take a bird out of a net; you will learn this in the field. However, we think these notes will help you as a reminder the next time you get to take a bird out of a net. We hope that you will get to do this kind of work often because it can be lots of fun, is a great way to learn about the birds of PNG, and it produces really good data even if you are relatively new to ornithology.

Being in the net is stressful for birds. They struggle, the net might cut them a little, and they cannot eat or drink so they become very tired. It is important to check nets about once an hour or every 45 minutes. A bird might get caught in the net as soon as you leave, so you should come back within 45-60 minutes at the longest, otherwise they are struggling too long. The feathers of tangled birds become unarranged, thus they can become cold if you are netting at high altitudes. Likewise, if it starts to rain, the water can run right onto the bird's skin instead of rolling off the feathers. Netted birds can die quickly if caught in the rain. It is very important to keep a close eye on the weather and ***close the nets if it begins to rain.*** Nets should be closed at night unless you are planning to work in the night also, checking the nets for bats or nocturnal birds like owls. If you leave a net open at night and don't check it you will probably kill some night birds or bats. You will also catch hundreds of beetles that are very tiresome to take out of nets!!! A general rule for netting birds and bats is to ***never leave your nets untended for more than one hour and never leave them open in the rain.***

A good trick to remember is to carry a small vial of sugar water with you. Most nectar-feeding birds (and bats) in PNG will drink from such a vial. The drink re-energizes them very quickly even when they are fairly exhausted. You

will be amazed how much sugar water some little birds will drink!

To close a net you first remove every little thing that might be caught in the net-- bugs, leaves, twigs, etc. We will show you the best method for twirling a net closed in the field. If you do it wrong you can accidentally catch birds and harm them, or have a very difficult time opening the net the next morning. If you did not remove all the debris from a net before you closed it, you will find it almost impossible to open. Believe us—it saves a lot of work to keep your nets clean of debris!! It is important to pick all the debris out of nets as you check them all day long, then it is fairly easy to close them at the end of the day when you are tired. Also, birds can see a net when there is debris like leaves caught in it and they will avoid the net.

When you net birds you should have a data sheet ready-made for the project you are working on. A sample data sheet is shown in Appendix 1. Remember, it is very important to carefully plan and prepare your data sheets for whatever project you are working on. Data sheets keep your data organized and consistent. Data sheets make it hard for you to forget important data. For example, without a data sheet it is easy to release a bird and then realize you forgot to weigh it!

Before you release a bird check the entries on your data sheet and make sure you have filled-in all the appropriate boxes. Data sheets make it easy for you to later organize your data, enter it into a computer database, or make your analyses and reports. Always avoid recording data in a sloppy fashion, on scraps of paper, or inconsistently. Always record the date you collected data, always record the units you are using, always record the species, etc. Do not use abbreviations for data except standard units (g for grams, kg for kilograms). Six months later when you look at your data you might not remember what some other abbreviation meant. Always initial your data and have your name on the data sheet. No matter how carefully you record your data there are going to be some problems. But if you are even just a little messy with how you record your data, you will have even BIGGER problems and your study could prove useless.

To hold a bird properly, gently cup it in your hand with the head sticking out between your index and middle finger so the bird can breathe and see.

It might scream, but it cannot bite you in this position. Do not squeeze; hold just tightly enough so it cannot flutter its wings.

When the bird is properly restrained, you can manipulate it however you want. First you might band it with a numbered aluminium band.

Once banded (or ringed) you can measure the wing chord. This is done with a wing ruler and you measure the closed wing from the bend of the wing to the tip of the longest primary.

The bill culmen is measured with dial calipers. The exposed culmen measures from the edge of the feathers on the forehead to the tip of the bill.

The actual culmen extends from the bill tip to where the bill meets the skull inside the feathering.

Collecting and Preservation

Please see Chapter 4 for basic information about collecting specimens, e.g., why you should collect

vouchers and cautionary notes on when you should not collect them.

The best way to collect small birds caught in a mist net is to squeeze both sides of the ribcage under the wings, collapsing the heart and lungs. Make sure the tail is raised so the bird does not defecate on the tail. Large birds can be humanely killed with a lethal injection. When a bird has been collected with a shotgun you should immediately plug the throat with a ball of cotton and carefully plug all the wounds with cotton and some sort of absorbent powder (like corn meal or fine sawdust). This minimizes the amount of blood or gastric juices that will leak onto the plumage and either damage the plumage or make a lot of work for you to clean-up. Store birds that have been shot bill-first in a cone of rolled, stiff paper to protect the bird's plumage until you are ready to prepare the specimen.

A rough outline for skinning procedure is described below. These notes are just to help you learn the process and help you remember it. It is necessary to learn how to skin birds by practicing many times. It is a good idea when you are learning to skin birds to leave the most important specimens to the most experienced skinner in your field team. It is possible for a novice to irreparably damage a skin, so do not learn on birds that are rare or extremely valuable (even though every specimen is valuable). Your specimens will look better and better as you learn. You should continually try to improve your workmanship. A poorly-made specimen is still useful, but a well-made specimen is more useful and a delight for other researchers to work with. Your name goes on every specimen you make and people will use your specimens long after you die. It is a very enduring contribution to science and one that never decreases in value, only increases. Scientists around the world take note and admire people who prepare good specimens, even more than 100 years after the specimen was made. This is about as close to immortality and fame as we can get in biology!!

<u>An outline for skinning a bird</u>

1. Record on a museum tag the following data: Soft part colours that will fade (eye, bill, legs, fleshy places), mass, catalogue number. Put a plug of cotton in the bird's throat after weighing the bird (this keeps gastric juices from leaking out and soiling the specimen).

2. If you are a fast skinner, you can start skinning right away and later collect tissues after removing the skin. If you are a slow skinner, you should collect tissues first by making a small cut through the lower chest. Place liver and heart in buffers (ethanol or DMSO) or deep freeze. Place some dry cotton in the hole to stop blood from staining the plumage. Only do this if you are likely to take a very long time to prepare the specimen (several hours).

3. Make a shallow incision from the base of the sternum to the cloaca. Just cut the skin, do not cut through the abdominal muscles or penetrate the abdominal cavity. This is the only place you actually cut the bird's skin in the entire procedure.

4. Raise the skin from the muscle with a forceps and work the skin from the body with a blunt object (fingers are best unless it is a very small bird), working around the side to expose the thigh. Most people start with the bird's left leg.

5. Grasp the leg at the "knee" and push the thigh and leg muscles through the opening you have made.

6. Cut the joint between the lower leg and thigh and cut all the muscles and tendons connecting the thigh to the lower leg. This can be done with a single cut with practice-- don't cut the skin.

7. Peel the skin away from the muscles on the leg right down to the joint ("knee") where the tendons continue down beneath the un-muscled, scaly "shin." Cut away all the meat and tendons

from the leg and wrap a small bit of cotton around the end of the bone where you cut the joint.

8. Work the skin off the side and back of the bird on the left side, particularly around the left side of the cloaca. This will make it easier when you get to step 10. Pull the leg back right-side-out.

9. Repeat steps 4-8 with the right side of the bird.

10. Place the bird on its chest with the bill flat against the table. Work the skin up over the cloaca and pull it away from the sides toward the middle of the back. You can now work the tip of a fine scissors between the skin and the base of the tail. Cut through the spinal column at the base of the tail, being careful not to cut the skin or the bases of the tail feathers. This step requires a little practice, do not be discouraged if it seems hard!

11. Now the skin is separated from the legs and tail. You can work the skin off the body with your fingernails, scraping it away toward the neck, but be careful not to tear the skin. Work around the body, freeing some skin from the back and then from the chest. Continue this up until you have freed the skin from the base of the wings and the neck. The skin will be mostly inside-out with the wings pulled up alongside the neck.

12. You can now easily cut through the muscle and bone at the base of the wings where they join the chest.

13. Next continue working the skin off the flesh up to the head (the skin is now inside-out except for the head).

14. Carefully pull the neck over the base of the skull. Use your fingernails to push the skin where it folds from the skull, rolling it forward a little bit by bit all around the skull. It helps to work it over the bulge where the lower mandible articulates (meaning where it attaches to the skull). This stage is usually easy with just a little practice, but for birds with big heads and small necks (e.g., owls, *Pachycephala, Clytoceyx*) it is extremely difficult. Go slowly.

15. Once the skin is freed from the back of the skull you come to the ear openings. Simply pinch the skin between your fingernails right at the ear opening to sever it and pull the skin away. Now you can peel the skin up and over the eyes.

16. A membrane covers the eyes, connecting to the skin. Cut through this without cutting the skin or eye. Scoop out the eyes with forceps, grasping the optic nerve.

17. Chop the entire base of the skull off, so you have the skin with just the front 3/4 of the skull and the body with the back 1/4 of the skull.

18. If you have not done so, take tissue samples now. Remember to always use clean implements, rinsed in ethanol, for extracting the tissues and do not let any foreign matter contaminate the samples. Even a little DNA from the previous specimen, detritus like a gnat, or from your own fingers, can ruin your tissue sample. Label the tissue sample with your catalogue number.

19. Poke one tip of your scissors up from just inside the lower mandible into the eye orbit, then cut toward the back of the skull, through the back of the eye and brains, along the inside of the lower mandible, leaving it articulated to the skull. Repeat on the other side of the skull. Then poke the scissors up from the front of the "chin" with a tip in each orbit. Cut the muscle and septum separating the eyes. Now you can grasp that septum with your forceps and pull out most of the muscle and all of the brains in one piece. If some brain remains in the skull scrape it out.

20. Inspect and record the skull ossification (examine the bit of skull still attached to the neck also). I.e., is the skull translucent or is it opaque, with all of the bone fully formed?

21. Pull the skin down over the base of the tail, exposing the uropygial gland. Scrape away the gland and all the grease inside of it.

22. Pull the skin off the remainder of the wing. It can be pulled forward along the leading edge of the radius and ulna, but not along the base where the secondaries attach. Cut away the meat.

23. With a strong thread make a stitch through the skin where it is pulled-up over the bend of the wing (you will have to see this one demonstrated, it is too hard to describe!) and then through the same place on the other wing, holding the wings together about the distance apart they normally are across the back of the living bird.

24. Roll tight balls of cotton and place them in the eyesockets of the skull.

25. Turn the skin right-side-out. Rearrange the feathers on the head and wings so they sit naturally.

26. Twist a cone-shaped piece of cotton onto a straight dowel with a sharpened tip. The cone should be roughly the size of the body removed from the bird.

27. Slip the cone into the skin, working it up through the neck. Use the tip of the dowel to bulge the cotton eyes out. Then anchor the dowel into the upper mandible so the bill is pointing forward, not up, when the skin lies on its back.

28. Pull the skin down around the cone and stitch it closed with a couple of stitches. Tie the legs crossed onto the dowel.

29. Sex the carcass, examine the gut and record the remaining data on the tag (at least: location, date, notes on moult, fat, gonad size and condition, skull ossification, how obtained, habitat, whether tissues were collected, stomach contents). Copy the data in your catalogue and tie the tag to the left tarsus.

30. Preen the plumage and pin the bird for drying or gently wrap it in cotton for drying.

Congratulations-- you have just made a very enduring contribution to science!

As with plants, fish, mammals, insects, etc., the most important part of the specimen is the specimen data, which should be fully written on the specimens tag(s) and in your collecting catalogue. The more data you include with the specimen, the more valuable the specimen becomes. Also, if the data with a specimen are unreliable or illegible, then the specimen becomes of very little value. Take particular care to always accurately and clearly record all the appropriate data for whatever specimens you collect as a biologist. There is much data enclosed in the specimen, but that becomes useless if we do not know when or where the specimen was collected. A specimen without data is like having a book in code and not knowing how to decode it.

CHAPTER 7: Mammals

Introduction

As far as we know, New Guinea has 212 species of indigenous mammals (those that either evolved here from ancient animals, or got here on their own by flying, swimming, or rafting on logs, etc.), 13 species of introduced mammals (those that man brought either on purpose [like pigs and dogs], or accidentally on boats or airplanes [like rats]), and 15 species of extinct mammals (Flannery 1995). The number of known indigenous species increased from 187 to 212 in the five years between the first edition of Flannery's book *Mammals of New Guinea* in 1990 and the second edition in 1995. This gives you an idea of our state of knowledge-- not very good yet! Of the 212 indigenous species, 112 are endemic to the island of NG (which means they are found nowhere else on earth) (Flannery 1995). Perhaps because mammals are more difficult to observe in the field than birds (mammals are often more secretive and many are nocturnal, meaning active only at night), we know far less about mammals than birds. There is a good guide to bats of PNG (Bonaccorso 1998). But for many mammal species, we know little about their distribution within NG, and virtually nothing about their population dynamics or ecology. Such knowledge is crucial to conservation efforts for these species, especially for those large mammals that are hunted.

Survey Techniques

Because mammals are more difficult to observe than birds, survey techniques rely less on observational methods and more on actually capturing the animals. However, some observational techniques are still used.

If you only want to document presence or absence of species you can generally search for mammals and their signs. However, if you want to make density or abundance estimates to compare sites you need to use standard sampling units. In this case, mammalogists (people who study mammals) use timed transect walks to record visual observations of mammals in a standard, comparable fashion. These can be done in the day or night.

Diurnal Transects

Remember that some NG mammals are diurnal (active in daytime) or crepuscular (active at dawn and at dusk) and so can be observed in daylight. But in addition to recording visual mammal sightings biologists also record mammal signs on these timed walks. For example, you will record any droppings you find and will try to figure out what species is responsible (usually you can only identify the group—like cuscus). Or you will record tracks left in the mud or sand and try to say if a wallaby, a rat, a cuscus, or a bandicoot made the track; often the shape and size of the track can narrow down which species it was. Or you may note and record scratching marks on tree trunks, etc. You will record any "mashes" left by bats when they have eaten fruits. Sometimes you can even identify the species of bat that ate the fruit by the size and palate impressions left on the

mash (bats squeeze fruit pulp between their tongue and the roof of the mouth, the palate, to suck out the juice of the fruit and then spit out the remaining hard pellet which is the "mash"). To be effective at this kind of survey, you need to know the tracks, droppings, and other signs of different animals. Sometimes, the biologist will even have bait stations along the transect to draw animals in and increase their chances of seeing signs left by the animals. If you do this, it is very important to record how many bait stations you used, where they were along the transect, and what kind of bait you used. Keep in mind too, that you cannot compare a transect with bait stations to one without bait stations; the methods for all of the sites you want to compare must be the same. Likewise, if you search 5 m on either side of the transect for signs, and take 1 hour to walk 1 km, this needs to be consistent from site to site if you wish to compare your results. If you wish to compare relative density or abundance between sites, your search effort needs to be consistent, or at least in standard units that can be compared.

Nocturnal Transects

Because most mammals in NG are nocturnal, mammalogists also do timed transect walks at night using bright spotlights. They shine these lights around on the ground and up in the trees to see if they spot any mammals. The eyes of many nocturnal mammals have a special membrane behind the retina that reflects light back out; this is a way for the animal to see better in very low light conditions. It lets us notice the animal more easily because their eyes seem to glow in the dark when we shine a flashlight at them (spider eyes also do this--their eyeshine is usually blue or white). The eyes of different mammal species will often shine different colours from each other; if we know what colour the eyeshine of a particular species is, it makes it easier for us to be sure of the species we are seeing. When we see a mammal at night, and can identify its species name, we should also record its eyeshine color so we can begin to make a list of these for NG mammals.

Transect Data

Whenever you do a transect walk, record your name, the date, the location, when you started the walk and when you ended it, how far you walked, whether you used bait stations, etc. Record what kind of habitat you walked through (e.g., old gardens, intact forest, etc.) and in which habitat type you saw each animal or sign. Record any other notes you think could be useful—was the cuscus 10 m up in a tree eating the leaves of an orchid? If you collect droppings or mashes give them a catalogue number and preserve them in ethanol with a label. Take photographs of scratch marks or echidna digs as vouchers and record these in your catalogue with a number that will go with the photograph. Perhaps you will even be lucky enough to get photos of the mammals you see as vouchers.

Capture

Mist Nets

Like birds, bats can be captured with mist nets set near fruiting trees, over streams, or along natural flyways such as trails. When you run mist-nets, you should record the date of all of your captures, and you should draw a map of where the nets were placed with a number for each net. Put a piece of flagging tape with the net number written on it on the net pole and every time you catch something in that net, remember to record that it was captured at that net number. Record the habitat type where each net was placed (that way you might be able to learn which species prefer which habitats); e.g., was it running across a stream? Instead of repeating basic information about setting and running mistnets we ask that you please read the section on mist-netting in Chapter 6 (birds) for important information you will need to know.

Bats struggle in nets and become severely entangled, like birds, so it is best to check the nets at least once per hour. When you find a bat in a

net, first you must decide which side of the net the bat hit and you should work from this side. You should pull the large pieces of net away from the bat and you should be able to expose the belly with no net fibers on it. Then you begin untangling its feet. Wear a glove or use a bag and allow the bat to bite this instead of your fingers! Once the feet are untangled, hold them gently so they don't become tangled again and work your way up the bat's body. When you are at the wings, do one at a time, by moving the strings away from the body and up and over one of the forearms. Once the strings are all past the forearm, they should easily slide off the rest of the wing. Do this to each wing. When the first wing is untangled, hold the elbow between two of your fingers and when the second wing is untangled, add the second elbow to this hold. In other words, you will be holding the bat so that the knuckle of your second finger is between the wings and your first (non-thumb) and third fingers are on either side of a wing, pinning them in place. If you hold the bat this way you will not hurt it and the bat cannot bite you. Lastly, gently remove the strings from the neck and head.

During this whole procedure you should be very careful not to hurt the bat. Look out for it because it is too frightened to look out for itself. Make sure that none of the strings are going across its eyes if they are open. If you have more than one bat in the net, remove them all before you start to make your measurements. You can put each in its own holding bag then hang these bags up (either on your belt, or on a net pole or vegetation). Use cotton bags or other materials that will allow airflow so the bats can breathe. Make sure the top of the bag is sealed (either by tying a string around it, or with a rubber band) so the bat can't get away! Put a piece of flagging tape with the mist net number on the bag; this will help if for some reason you have to bring the animal back to camp to process it. You will know where you caught that particular animal for your records, and you will know where to take the animal back to release it. ***Always release an animal at the exact same spot you captured it.*** You have no idea how far its home range extends (the area it usually wanders around in) and so it may be lost if you release it somewhere else (some rodent home ranges are only 20m long and some bats range less than one km). You wouldn't want to be put down 200 miles from your home and have to find your way back, would you?! Releasing animals in the wrong place could also mess up future genetic studies of the area; be kind to future researchers and to animals.

Do not run mist nets in rain as captured bats can die from hypothermia. Begin closing your nets as soon as you know it will rain. In PNG it can be extremely difficult to net bats because it rains almost every night. After a week of rain from 6 to 10 at night we have gotten up and run the nets from 2 to 6 in the morning instead as it was not raining then. Also, when

Learning to extract bats from mist nets takes practice. It can help to have one hand gloved to allow the bat to bite the glove while using the free hand for the delicate work of taking the net off the bat.

Nectarivorous bats are especially prone to exhaustion after being captured in nets. You can help revive them by feeding them sugar water from a syringe without a needle. Just let them lick it from the end of the syringe. You will be amazed at how long their tongues are as they reach to get it!

you are netting with a river between your camp and the nets, you should stash some warm dry clothes and a tarp at your nets. By the time you have closed all of your nets the river may be too high to cross and you will be stuck on the other side for the night in the freezing rain (we are talking from experience!). Read the safety chapter—rivers rise incredibly fast in PNG and are extremely dangerous when they do. Just sleep on the other side instead of risking drowning.

As with nectarivorous birds, you can revive tired nectar-feeding bats by letting them drink from a vial of sugar water—*Syconycteris* love this! Make sure you weight the bat BEFORE you give it sugar water as it will greatly affect mass after their belly is distended with sugar water!

Another thing to remember—always record how many nets you ran each night, the size of the nets (mesh size and length/width), and the time you opened and closed them. That way you know the number of net-meter-hours you sampled to capture the number of bats you got (how many meters of net were used times the number of hours they were run). You need to know how many of these standard sampling units you used to be able to compare capture results.

Harp Traps

Bats can also be captured using Harp traps. Mist-nets catch bats that use vision (flying foxes), but you usually need harp traps to catch bats that use sound (echolocation) to "see" their environment. Harp traps consist of a rectangular frame with fishing line strung up and down every few centimeters; there are two "banks" of these vertical fishing lines and they are offset from each other. This way the echolocating bat senses the first bank, or series, of lines, and he/she turns sideways to fly between the lines-- the bat thinks it is outsmarting the trap. But when it does this, it hits the second bank, because it is offset, and the bat is stunned and it drops down into a collecting bag below where it waits for you to come and get it out. Convenient, eh? You don't have to check this kind of trap as often as you do mist-nets, because the bats are pretty comfortable in the holding bag. However, if you think you might catch two kinds of bats that will fight with each other, you should check the bag often! You can hold the bats the same way you would when you take them out of a mist-net, by the elbows, or you can cup them in your hand with your first finger around the back of their neck and your thumb around the front of the neck-- gently!!!!

Record the number of harp traps you used each night, their size, and the times they were opened. Also record the habitat they were set in and any special remarks—was the trap set across a stream?

Live Traps

For mammals that can't fly we use box traps, usually called "live-traps" because the animal is just captured, and is not killed or hurt. These traps consist of an enclosure where the doors are held open by a trigger mechanism that is connected to a treadle on the floor of the trap. When an animal enters the trap, it steps on the treadle and the doors instantly close, trapping the animal inside. Mammals can be lured into these traps by baiting them, or the traps can be set along natural walkways, like a log going across a stream. The traps can have either a door on only one side, or they can have a door on each side of the trap that the animal can enter. Trap nights (number of traps set times the number of nights they were set) make a good standard sampling unit.

Traps should be set to take advantage of the nonrandom fashion in which mammals use their environment. You should look for signs of mammal activity, like gnawing, or tunnels or trails, burrows, droppings, or footprints. When you see these signs, put traps in that area and place them so they are camouflaged as well as possible, and are level with the ground so that the animal doesn't have to climb up and into the trap, but can walk naturally into it. Make sure the trap is securely in place-- you don't want the animal walking into the trap and then have the trap tip one way or the other so that the animal is frightened and backs out of it. When you set the

trap, you can put sticks into the ground on either side to anchor it down and keep it stable. With big traps, you can also put small logs on top of the trap to keep it in place. Be especially sure to anchor traps well in areas where you might have wild dogs that will carry away the trap with the animal inside. You can also put guides, like stones, or sticks, going out on each side of the trap to guide the animal into it (because the animal doesn't want to bother climbing over your sticks). If you think it's going to rain, you should put lots of leaves and moss on top of the trap if it is not a solid top, to make sure the animal doesn't get soaked and cold after it is captured. If it is hot where you are working, you should make sure you check your traps very early in the morning to make sure the animal doesn't over-heat-- especially in metal box traps. If it is cold in the area you are working, you should put some nesting material (e.g., cotton wool) in the trap so the animal can stay warm.

What you catch has a lot to do with what kind of bait you use in your traps. It is a good idea to try several different kinds of bait during the course of a survey. The bait should be placed behind the treadle so the animal has to walk on the treadle to get to the food. Make sure the debris or bait is not caught underneath the treadle or the trap will not work. The bait you use depends on the animal you want to catch; to catch rats people usually use rolled oats mixed with some peanut butter to make it smelly. You can also use fruit or dog food as bait. If you want to catch something carnivorous, you might want to use some kind of smelly fish. Sometimes it works to catch large insects (like cicadas [Homoptera] or katydids [Orthoptera]) and put them in a small net bag in the back of a trap. The smell and noises they make can attract small insectivorous mammals. Basically, you want something that is edible and smelly or noisy and thus attracts mammals to the trap.

Once your trap is set, spring the release to make sure it works. Sometimes the trap is a little off-square and the doors get caught and don't go down all the way-- you want to fix this BEFORE you leave the trap open for mammals. If you find traps that are tripped but empty, you might suspect that the door did not close properly and the mammal that triggered the trap got away. If mammals escape from your traps, your trapping data becomes inaccurate and you won't even know it. If you are worried that the animal will sense your smell on the trap if you reach your hand inside to trip the trap and check that it closes properly, you can use a stick, or wear gloves.

The most important things in trapping are to make sure you ***do not forget where you put your traps***, make sure to ***check the traps at the right time,*** and make sure you ***check all of your traps and do not forget any.*** You must draw a map in your field book showing the positions of all of your traps on it. Tie a piece of flagging tape with the number of the trap site written on it to a branch by each of your traps so you can easily find the traps. You should also have the number of the trap site on your trap so that if you have to take the trap back to camp to process the animal, you will know where to bring it back to. It is extremely important to ***ALWAYS release an animal at the exact same spot that you captured it*** or the animal may be lost and unable to find its way home (to its family and familiar surroundings). You could also be messing up home range and genetics studies that other researchers may want to carry out.

When you set out your traps you should write down the micro-habitat where each trap is placed (for example, "trap 3 was by a small stream and was placed along the side of a fallen log"). You should also record the habitat type (for example, primary forest or re-growth forest). This can help you learn the requirements for each species (can they live in re-growth, or do they have to have intact forest?) (see Laurance 1990). If you are trying to catch animals that are only active at night, you should set your traps in the late afternoon and check them first thing in the morning once it is light; you should then leave the doors of the traps closed during the day so no other animal is captured by mistake. If you want

to try to catch animals that could be active at night or during the day, you should leave the trap open all the time, and check your trap first thing in the morning, but you should also check your trap several times during the day. This is especially important in hot climates. The metal boxes can act like ovens. Also, ants can come into the traps and the trapped animal cannot escape them; the ants will literally eat them alive—traps with ants need to be washed and re-located to another place; otherwise the ants will just find the trap again. ***Never leave an animal in a trap longer than is absolutely necessary.***

You should also set traps up in the trees by tying them to branches and lianas, or by constructing places for them at branch points. Malcolm (1991) set traps in the canopy and used a pulley system to get them up and down for baiting and when he captured something; he was able to catch species no one else had captured before. Again, make sure the trap is securely in place and try to make the trap so it is as horizontal as possible. Some animals rarely come down to the ground and you will not catch these species unless you trap up in the trees. You can also use pitfall traps (buckets with slippery sides placed in holes in the ground) to catch animals that will not go into your other traps. Different trapping methods will catch different species of mammals, just as using a different kind of bait will (Laurance 1992). If you catch a mammal in an open-mesh trap (not solid-walls), cover the trap with a cloth like a burlap or ditiman bag so the animal is in the dark and unable to see people while you are waiting to process it. This will keep the animal from becoming too agitated and possibly injuring itself by struggling.

On surveys we usually set standard trap lines so they are comparable from site to site. We run four trap lines along trails or transects, each with 40 trap sites spaced 20 m apart. The first trap site is at least 50 m from our campsite. Each site has one Elliot trap placed on the ground and one tied into place 1.5-2 m or more above ground (on a tree, liana or log across a stream). Traps are placed in selected micro-sites as described above, not just plopped down at the 20 m mark. We also place one larger Tomahawk trap at every 2-3 trap sites to catch larger mammals; these are usually on the ground or on logs across streams. We run trap lines for 3-4 nights each. We normally use peanut butter and oats in the Elliots and biscuits, tinned fish and peanut butter in the Tomahawks as our standard bait.

One more note— mammalogists in temperate regions use "Sherman" traps but in PNG it is best to use "Elliot" traps. They are longer. Sherman traps will cut off the tails of many PNG rodents when the door snaps shut.

Snap Traps

Mammals are sometimes captured in snap-traps which kill the animal. These traps have a small, usually wooden platform where a bait is placed. The platform is attached by a trigger mechanism to a spring-loaded bar so that when the animal removes the bait, the trigger mechanism releases the spring-loaded bar which then snaps down onto the animal, killing it. Snap-traps are small and are light weight, but they kill the animal. This is a big drawback if you want to study the community you are working in. Snap-traps should only be used in quick inventories where you will be killing and preparing specimens from all of the animals you capture. And they should only be used in places where you know there will be no studies to monitor the population (because you could alter the population by killing many animals).

Sticky Traps

You can use sticky traps which are often sold as mouse traps—they are sheets with glue covering them. You can place these on tree trunks, on the ground, or wherever you think a mammal might walk by. Make sure they are secured in place so the animal doesn't wander off still stuck to the paper! Again, make sure to record the location of these traps and make sure you check them all at the appropriate time as with all other trap types. You can remove any captured animals with vegetable oil which will dissolve the glue.

Snares

Snares are a traditional method used in PNG for capturing mammals and cassowaries. Some will kill the animal (like the neck snares used for cassowaries), but others will only loop around the animal's leg (like those used for bandicoots). Snares can be another method for your surveys.

Handling

Once we have captured an animal, we can immobilize it using Ketamine hydrochloride so data-collection and handling are easier for us and for the animal (e.g., Salas and Stephens 2004). This drug makes it so the animal cannot move its muscles; the animal will be limp and cannot bite you. You have to look out for the animal when it is under the influence of the drug. Its eyes will be open and unprotected (they cannot blink), so make sure that the eyes don't have bright lights or sunshine on them, and make sure that the eyes aren't on the ground, getting rubbed with dirt. If the animal is very small (under 50 grams) you should handle it without using a drug because it is too difficult to get the proper amount of the drug into the animal. Hold it with its neck between your thumb and first finger-- gently. Do not hold it by the skin on the back of its neck like you would a kitten; this skin tears easily in some species (esp. *Melomys*). Likewise the sheath of the tail will tear off in some species (esp. *Melomys*) so unless the tail is robust like in a cuscus, do not hold it by the tail!

The first step is to get the animal out of the trap and into a bag so you can handle it. Wrap a cloth bag (like a pillowcase) around the mouth of the trap and make sure it is tight so the animal cannot escape. Then open the door of the trap through the bag and give the trap a shake so that the animal falls down into the bag. When the animal is in the bag, release the trap door so the animal will not crawl back up into it. Be very careful not to catch the animal's tail in the trap door. Tie a string or rubber band around the mouth of the bag and hang it up somewhere so the animal cannot escape. This part can be exciting because the animal will move very quickly, trying to escape, so try to remain calm.

Next, you need to draw up the correct amount of anesthesia (the Ketamine). Use 20 to 40 mg of Ketamine for each kg the mammal weighs. Because Ketamine usually comes in a solution that is 100 mg per ml, this means that you will be giving the animal 0.2 to 0.4 ml for each kg of the animal's body weight. If you do not know how much the animal roughly weighs, then you need to weigh it while it is inside the bag (remember to subtract the weight of the bag and the string tying the bag to get the animal's weight). Multiply the animal's weight in kg (remember that 1000 grams is one kilogram, so if your animal weighs 90 grams, it weighs 0.090 kg) by 0.2, 0.3, or 0.4 (the multiplier depends on how long you want the animal anesthetized and what its metabolic rate is, e.g., more for faster metabolic rates because they use the drug up faster). That will tell you how many ml to inject into the animal's muscle. For example, if your animal weighs 140 grams and has a fast metabolic rate, like a rat, you should give it 0.14 X 0.4 = 0.056 ml of the drug. If your animal weighs 2.4 kg (2400 grams) and has a slow metabolic rate like a possum, then give it 2.4 X 0.2 = 0.48 ml of the drug.

We use Ketamine because it is a relatively safe drug, and even if you give the animal a bit too much for your purposes, it will not hurt it. If you must use inhalant anesthesia be extremely careful as you cannot precisely control the dose—it will depend on how fast the animal is breathing.

Once you have your syringe ready, move the animal inside the bag so that its head end is facing down towards the closed end of the bag (but it can still breathe) and the tail is towards the end that you can open. Hold the animal in place firmly and pull the back end of the bag up to reveal the animal's rear end. Inject the drug into a big muscle. The hip, or the thigh, depending on which has more meat on it. Make sure to get the injection into the muscle, not just under the skin and not too far into the animal. Try not to

hit any bones because these will bruise and will this will hurt the animal. Be gentle, but be quick so the animal doesn't have a chance to squirm around. Be extremely careful not to break the needle off in the animal-- this is why you must be very quick: get the needle in the right place, inject the drug, and get the needle out of there. Make sure you have not hit an artery or vein or you can overdose the animal; the shot should be in the muscle tissue. Next, close the bag with a rubber band or tie and hang it up or put it somewhere safe until the animal is not moving anymore and is feeling the effects of the drug (usually only a minute or two). Now you are ready to take the measurements and find out what species you have.

When sedated with ketamine, mammals are still conscious and alert, but they cannot move their voluntary muscles. Thus you need to take care to make sure they are not injured, especially their eyes.

Always allow the sedative to fully wear off before releasing a mammal back to its environment. Be sure to release the animal exactly where it was captured so it is not disoriented and so future studies are not compromised.

Note that this rodent is held gently with its head between two fingers so it cannot turn and bite the researcher.

Recording Data

Once we have captured an animal we need to identify it and measure it. Compare the animal to the information in your mammal books to identify it to species, and/or use a dichotomous key (keys will be talked about in the course). We need to record all of our data, preferably on a pre-made data sheet.

These are the measurements you should take for mammals:

Mass (g): Weigh the animal while it is in a bag, then weigh the bag and subtract the weight of the bag from the total weight to find out how much the animal weighs.

Head and body (HB) (mm): Flatten the animal out on a table or the ruler, and measure it from the tip of its nose to where its tail starts—you can feel the hipbone at this point. Some people measure ***Total Length (TL)*** instead, which is a measurement from the tip of the nose to the tip of the end of the tail. As you can see, if we add HB to tail (TV), we get TL, so as long as you measure TV and either HB or TL, you can figure out the other one.

Tail, or tail vertebrae (TV) (mm): Either feel where the tail begins and measure from here to the tip of the tail, or hold the tail in the air and put your ruler where the tail begins (where it bends, starting to go up in the air) and measure to the tip. Don't include any hairs going out past the tip of the tail, only measure the flesh and bone part.

Ear (mm): Measure from the bottom of the notch near the base of the ear to the top of the ear.

Hindfoot (HF) (mm): Measure from the back of the heel to the tip of the longest toe with the foot and toes flattened out. Some people include the claw of the toe, and others stop at the end of the toe and do not include the claw. Make sure you record which you are doing along with your data; you might even want to give two measurements, one with claw and one without.

For bats we also record:

Forearm (FA) (mm): Use calipers to see how long the forearm bone is while the wing is folded up.

Tragus length (TR) (mm): The tragus is the small flap of skin that sticks up inside the ear of some kinds of bats. You measure how long this is from the base at the inside edge where it meets the head, to the tip.

Wingspan (WS) (mm): Lie the bat face down on a cloth and spread its wings out and measure the length from the one wing tip to the other. Be careful not to hurt the bat when doing this. This measurement is optional-- you do not have to take it.

Identification

You also need to record the species (or at least what species you think it is; if you are not sure use a question mark).

Sex

With placental mammals, look for bulges near the base of the tail that represent testes in males, and look for the vagina in females. Males have one opening (the anus) in addition to the penis, but females have two openings (the vagina and the anus) in addition to the clitoris, which may be enlarged and look like a penis in many small rodents. Male marsupials have their testes in a sack that hangs off the abdomen by a cord, and marsupial females have a pouch with the nipples inside. If you are not sure what sex the animal is, put a question mark.

Reproductive status

For males, record whether the testes are small (not noticeable), medium, or large (the size of the testes in many species depends on the season or the age of the animal). For females, examine the vagina-- this may be open (perforate), or it may be closed over by a membrane (imperforate); you should record which of these it is. You can gently pinch the skin just posterior to the vagina and pull up a bit the see if the opening is open or closed over if it is difficult to tell. Look for the nipples-- in placental mammals they are axillary (under the arms) and/or abdominal, on either side of the belly. Nipples are always bi-laterally symmetrical (the same number on each side of the body mid-line). In marsupial mammals the nipples are inside the pouch. You need to record the number of nipples and where they are; for example, on a rat, if there are two on each side up on the chest and another two on each side down on the belly, you record 2 + 2 = 8 (because there are 8 total, four on each side). This is called the mammary formula. If the nipples are tiny the animal is either a male, or a female that has not been pregnant yet. Record this. If they are large then it is probably a female and she is either pregnant now, or has been in the past. Record this and note the color of the nipples (pink or dark-- dark usually means she is post-lactating, in other words, she has had young before, but they are already weaned; if they are large and pink, she is probably lactating, is about to, or has just stopped). If the nipples are large, give them a gentle squeeze to see if any milk comes out and then record whether the female is lactating or not (has milk); also note whether the mammary glands are swollen and distended. If it is a female bat or rat (a placental mammal), feel the animal's belly to see if you feel a hard ball-- if you do the animal is pregnant; you can tell how far along she is by how big the ball is-- record this. If it is a bat, sometimes you can feel the wings of the embryo-- if you feel these, then the mother will soon give birth—she is third trimester, record this. If the animal is a marsupial, you can look in its pouch to see if it has any babies and you can measure them and record the number and sex of each. Be careful not to remove the babies from the nipples because for a long period they must stay attached to them while they are growing. If removed, they may not be able to reattach to the nipple and they will die.

Age

If the animal is a bat, you can shine a flashlight behind the wing bones to see if they have epiphyseal cartilage plates near the joints; with age these areas become mineralized and turn into bone, but in juvenile bats, they are cartilaginous and the light will shine through them. If you cannot see through the joints, the animal is an adult; if you can, it is a juvenile; record this information. Toothwear can also help you estimate an animal's age.

As you can see, this is a lot of information to remember to record and it is often easiest if we

already have these things written at the top of columns in our data books or on data sheets so we remember to record it all (in other words, ***have datasheets pre-written***, see Appendix 1). You must also write down the study site, the date, the time and the mist-net or trap number where you captured the animal.

If you have anesthetized the animal, wait at least two hours before you release it back at its trap site (make sure it is completely recovered from the drug and is active and mobile). Do not return a drugged animal to the field too early-- it might become an easy victim to a predator if it is not alert, or it might injure itself.

Recapture

When we catch an animal we usually mark it in some way so we can tell that we have captured it before. We can use ear-tags, ear-notching, toe-clips, or colored beads (Salamon and Klettenheimer 1994) on small mammals, and we can use wing bands or necklaces on bats. Toe-clips and wing bands are not used as much as they once were as they can cause injury to the animal. These are all relatively permanent marks that will identify individuals. More recently PIT tags (Passive Integrated Transponders) are commonly used to permanently mark animals. PIT tags are small microchips which have a unique number and letter combination. They are injected subcutaneously (under the skin) using a 12-gauge hypodermic needle and syringe. The size of the needle and the chip means that PIT tagging is unsuitable for many small species (particularly small microbats). Specialised equipment is required to read the tag numbers.

If you are doing a survey and not an ecological study, you will probably only want to know how many individuals you capture, and don't need to know which ones you caught where or how many times. To do this, you can cut a patch of fur off the animal or if it is a bat, you can make a small pinhole in its wing membrane. These methods do not harm the animal, the fur will grow back, and the hole will grow over, but they will let you know if you have captured that animal before during this study. This is all you really need if you are doing a quick survey in an area and only want to find out how many individuals of each species you catch. Obviously you need to mark them somehow-- if you do not, you could catch the same two animals over and over, and conclude that the abundance of that species is much higher than it really is. By marking the animals, you do not make this mistake.

Collecting and Preservation

In order to identify some mammals we will unfortunately have to kill them and preserve them. We can then take these specimens to a museum and compare them to the specimens there to try to find out the correct species name. You should never kill an animal unless you have to-- especially rare, endangered species. However, in order to prepare vouchers, and in order to get a properly identified list of which species live in an area, we sometimes have to collect specimens (see Remsen 1995).

Small mammals can be killed by squeezing the chest cavity, as described for birds. Make sure you do this while the animal is in a bag and while you have gloves on so it cannot bite you. Larger mammals are best killed by overdosing the animal with anesthesia, or by injecting a euthanasia drug into the chest cavity. If you crush the animal's skull, the specimen will be ruined, and if you drown the animal, you will be putting it through a lot of suffering. We should be humane to animals. To kill an animal by overdosing with ether, put it into a sealed container with a wad of cotton that has been soaked in ether. Leave the animal in the container for 5 minutes plus an extra 30 seconds for every 100 g of body weight over 1000 g (Barnett and Dutton 1995). The animal will simply feel like it is falling asleep. Be careful with ether-- it is very flammable, do not smoke near it or have any fires by it or you might have an explosion. Also, it turns from a liquid into a gas any time it is not sealed up-- do NOT leave a container with ether open, always put the lid back

on it tightly right away. Any mammal that weighs over 1 kg, that you need to collect, should be killed by injection of a euthanasia drug into the chest (for example, sodium pentobarbital).

When you kill an animal to prepare a specimen, you should get as much information from it as possible. You should look at the reproductive organs to verify its sex, and you should cut open its stomach to record what it has been eating (you might find insects, or seeds of fruits, etc.). You should also preserve the heart and liver in a buffer or 90% ethanol so that DNA can be extracted from it. Museum specimens of mammals can either be a dried skin with a skull to go with it, an entire skeleton, or a fluid-preserved specimen, which is the whole thing fixed in formalin and then stored in ethanol. Often bats are preserved whole, because you identify many bats by their nose leafs which shrink too much with drying.

Preparation of museum tags

Keep a catalogue with all of the data recorded in it for each specimen. Each specimen will have a unique number in your catalogue. Museum tags should be made of rag-paper (natural fiber, so they are more durable than regular paper) and are attached to each specimen. These tags are crucial-- without a data tag the specimen is useless.

On the tag record:

- The specimen's field catalogue number (which will start with your initials or name).
- The date the specimen was collected.
- The location you captured the specimen, including latitude, longitude, and elevation.
- Sex, genus, species, and age class.
- All measurements (mass, HB, TV, ear, HF, FA, TR).
- All reproductive and mammary data as recorded on your data sheet.
- Stomach contents.
- How the specimen was collected (net, live-trap, sticky trap, hand capture, etc).

Make sure you use water- and ethanol-proof ink, or a pencil, when writing this information!

Preparation of fluid-preserved specimens

First record all data and measurements then inject 10% formalin into the large muscles, body cavities and brain. You should pin it to a board in the position you want it to remain as it will become stiff. At this point, make sure you tie a museum tag with all of the information about the animal (measurements, etc., as listed above) to the animal's tibia (leg bone); sew it through the membrane if you need to on bats. Leave the specimen to soak in 10% formalin for 3-5 days. After the 3-5 days, take the specimen out of the formalin, rinse it in water, and transfer it to 70% ethanol for long-term storage.

Preparation of skeletal specimens

To make a skeleton specimen, you strip most of the meat off the animal. Then put the cleaned skeleton in a gauze bag with a museum tag with all of its information inside the bag. Dry the specimen so it becomes hard and will not rot. Back at the museum they usually use beetles to chew off the remaining tissue. You should be careful not to get any chemicals on the skeleton because the beetles will not clean the meat off the bones if they taste nasty chemicals like formalin.

Preparation of mammal skin, skull and DNA specimens

1. To prepare mammal skins you should stretch your wires first-- grasp the wire (thickness of wire depends on the size of the animal) in pliers and pull until it is straight and non-elastic. Make sure you use wire that will not rust (usually Monel wire). Cut a piece for the tail measuring from the lower tail-tip to mid-body. Cut limb wires measuring from the pad of the paw to a third of the way into the body cavity with the limb stretched out straight and parallel to the body. Although some people do not use limb wires, they are useful in preventing the loss of limbs as the specimen ages or if it is roughly handled.

2. Now make a cut in the belly with a scalpel or scissors, either vertically from just under the navel to just above the genitals, or horizontally across the hips. Be careful only to cut the skin and not

the gut wall. Gently separate the skin from the gut wall and work your way down to one of the thighs and push the hindlimb out. Sever it at the knee (but for small bats, sever at the hip). Remove all of the muscle and tendons from the remaining leg bone down to the ankle. Now do the same to the other hindlimb.

3. Next work the skin off the rest of the lower body and cut the genital and anus tubes from inside the skin. Now start peeling the skin down the tail; once you have enough of the vertebrae exposed you can use forceps to grab the base of the tail and with your other hand, slide the skin the rest of the way down and off of the tail.

4. Now work the skin off the body cavity down to the forelimbs. Remove one forelimb at a time, severing at the elbow. If you are working on a bat, break the forelimb midway down the humerus (the bone closest to the body). Remove all muscle and tendons from the remaining bones down to the wrists.

5. Now peel the skin down off the neck and head until you reach the ear tubes; expose these all the way around and clip each close to the skull. Work the skin down and over the eyes. Each eye will have a clear membrane over it; carefully clip this clear membrane around the rim of each eye until the skin is free to be peeled farther up the skull. Clip the skin from the edges of the jaws until the mouth area is free. Now you just need to clip the skin off at the base of the nose. Consult Nagorsen and Peterson (1980) for pictures of each of these steps.

6. Now is the time to deal with the body. Using forceps and scissors washed in ethanol (i.e., with no foreign DNA cells), cut out the heart and a piece of the liver and place them in a vial with either a DNA buffer or 90% ethanol. Put an ethanol proof paper (rag paper) into the vial with the specimen number (your catalogue number) (the same as the number you use for the skin and skull). Make sure you use ethanol-proof ink or a pencil. Check the sex and reproductive condition of your animal; if you find embryos, measure them and preserve them in 70% ethanol with a label; measure the testes with calipers (mm)-- each one horizontally and vertically (e.g., 4.2 X 3.5 mm). Cut open the stomach and record any identifiable contents. Sever the head at the axis vertebrae and save it to deal with once you have finished the skin.

7. Remove any flesh or fat remaining on the skin. Next sew the mouth of the skin closed from the inside. Roll up a piece of cotton that is about the same size as the animal's head and body that you removed; roll the top sides of the cotton inward and grasp this point with large forceps. Place the point of the forceps at the base of the nose on the skin and roll the skin over the cotton body until the skin is right-side out again. Remove the forceps. If needed, you can manipulate the cotton, using smaller forceps, until you have a nicely shaped head and neck.

8. Now wrap the tail wire with cotton. Wet a tip of the cotton so that it will stick to the wire to get it started and twirl it around the wire tightly (roll the wire in the fingers of one hand as you smooth the cotton down on the wire with the fingers of your other hand). The cotton tail should be slightly smaller than the real tail in diameter. Continue the cotton down the wire and wrap it around the other wire tip (the one that will be in the body cavity) so there is not a sharp projection to poke out of the finished skin. Now insert the tail wire into the tail and lay the remaining wire into the center of the body cotton so that it is wrapped up in this cotton.

9. If you are not using limb wires, wrap the remaining limb bones in cotton so there are no sharp projections and so the volume approximates the volume of the muscle removed. You should not use limb wires for bats; you have severed the bones close to the body cavity and these bones will suffice (the patagium and uropatagium membranes will prevent the limbs from falling

off). If you are using limb wires, insert each so it is anchored firmly into the sole or palm of the limb, then tie the limb-bone to the wire with a piece of thread. Now wrap the wire and bone with cotton so that it is about the same size as the muscle mass that was removed, making sure to continue the cotton down over the end of the wire so there is no sharp point. You should anchor the free ends of all of these wires into the cotton body so they will not poke through the skin.

10. Next sew up the belly incision, always inserting your needle into the underside of the skin. Brush the animal's fur gently with a toothbrush and tie the specimen tag firmly to the animal's hindleg (sew it through the patagium if necessary on bats). Now pin the animal to a piece of cardboard or styrofoam so that the forelimbs and hindlimbs stretch out parallel to the body and lie close to the body-- put a pin in each paw to anchor it. Make sure the tail is stretched out straight and put pins on either side of it, crossed at the top, to anchor it in place. See Nagorsen and Peterson (1980) for illustrations. For bats, place a pin through the patagium at each wrist with the wings aiming downwards and another pin anchoring the bottom of the wing. If there is a uropatagium, pin the bat so this can be seen. See Kunz (1988) for illustrations. Fix the ears and eyes, etc., so the animal looks lifelike. Now it is ready to place in a drying box until it is stiff and completely dry.

11. Unlike a bird study skin, a mammal study skin does not have portions of the skull inside it. Instead, the skull is removed from the skin and labeled with the same specimen number as the skin. Gently sever the skull from the spinal cord at the axis and remove any flesh that will easily come off. Use tweezers to remove the eyes. Do not force meat off because you may damage the skull. Use a water filled syringe to wash the brain out of the cranium through the foramen magna (the big opening in the lower back of the skull) by inserting the needle into the brain and pushing the water out. The volume of the water inside the brain cavity will force the brain tissue out the foramen magna. Once the skull is cleaned, place it in gauze with a label and dry the skull in a drying box. After it is dry you can store it in a plastic bag sealed tightly with extra air inside to cushion it, or you can store it in a small cardboard box. Back at the museum, beetles will be used to eat away the remaining bits of flesh, so it is important not to get any chemicals on the skull. If you know you will not have beetles available, you can gently boil the skull and then remove any remaining flesh before you wrap it in gauze (but sometimes this will make the teeth loose and they will fall out, so using beetles is better). Both the skin and the skull constitute one specimen in the museum collection. At the museum the skull will be unwrapped, and once it is thoroughly cleaned the specimen number will be written on both the skull and the jawbone with water-proof ink.

Useful references

Detailed guides with useful pictures for making study skins and skulls are found in Nagorsen and Peterson (1980) and Kunz (1988). Kunz also covers a wide range of ecological methods to use with bats. Barnett and Dutton (1995) cover small mammal trapping along with a variety of other techniques.

CHAPTER 8: Herpetofauna

Introduction

Twenty-one families of reptiles and amphibians, collectively known as herpetofauna, occur in PNG. The genera within those families are fairly well-known. In those genera, there are approximately 505 species (Allison 1993), of which at least 175 are endemic (Osborne 1995). More species are being described every year in PNG, both from new discoveries in the field and from museum collections as existing genera are scrutinized for previously unrecognized species (Allison 1993). Despite our knowledge of herpetological taxonomy in PNG, we know very little about the basic biology and ecology of most species (Allison et al. 2004).

Two kinds of herpetological work are especially needed in PNG: 1) focused surveys at sites where little work has been done, emphasizing systematic work on herpetological species richness and, 2) ecological studies of amphibians to help us understand their biology so we can understand what is needed to conserve them. Very little is known about the ecology of most herpetofaunal species in New Guinea. Thus, with a little careful observation the student can make very significant contributions to our knowledge (e.g., Johnston and Richards 1993, Price 1994). Some useful references for herpetofauna surveys in PNG include: Malnate and Underwood 1988, McCoy 1980, Menzies 1976, Tyler 1968 and Zweifel 1972.

Producing a comprehensive inventory of the herpetofauna at any site must take into account a range of factors:

1. Although reptiles and amphibians are traditionally lumped together during fauna surveys they are in fact quite different ecologically. Thus a number of different approaches and techniques must be used to produce a comprehensive inventory. However, one feature of collecting both frogs and reptiles that sets them apart from most other animal groups is that collecting is very much a "hands on" process. Large nets and traps are of limited use. Survey success is often determined by the agility of the collector!

2. The diversity of frogs and reptiles will be strongly influenced by the range of habitat types and altitudes that are available for sampling. Frog assemblages in particular change dramatically with increasing altitude, and may be far more diverse in upland rainforest than in the lowlands. In addition, species living along streams are quite different from those living around ponds, or those living on the forest floor, or those in the rainforest canopy. When conducting a survey it is vital to first identify the range of habitats and altitudes that are accessible, and attempt to search intensively in each one.

3. Although the comprehensiveness of any inventory is determined by the time and effort expended in the field, it should not be expected that a single survey will document the entire frog and reptile fauna at any site, particularly the many

high-diversity sites typical of PNG. This is particularly true for species that are rare, cryptic, or active or calling only during certain seasons. Multiple sessions at different times of year are often necessary to approach a comprehensive inventory.

Special Conservation Concerns

There is recent evidence that many amphibian species are in drastic decline worldwide. It appears that in many cases amphibian populations are crashing due to infection of the chytrid fungus *Batrachochytrium dendrobatidis*. This fungus has wiped out populations of frogs in over three dozen countries and is likely responsible for total extinctions of some species. The fungus is not yet known from Papua New Guinea. Thus a first mandate for anyone working with amphibians in PNG is to take all possible steps to avoid introducing the fungus to the island.

Herpetologists visiting PNG from overseas should not bring any equipment that has been in contact with frogs anywhere else. Under no circumstances should any frog be imported to PNG for any reason. There is an international trade in frogs, much of it illegal, for pet trade. This should not be allowed to happen in PNG. Frogs should not be exported from New Guinea for any but possibly the most stringent research purposes. And for no reason should any of these frogs, or even containers or water that has ever contacted frogs outside of PNG, be allowed back into the nation. For example, a hiker who filled a water bottle in Australia and came to PNG and emptied that bottle in a stream along the Kakoda Track could inadvertently lead to the introduction of the fungus and possibly create an environmental catastrophe for PNG.

The fungus is suspected to be moved easily through the pet trade and even businesses farming frogs' legs as food. Frog farming and trade is thus extremely risky in a nation like PNG that is chytrid-free. Once such a pathogenic fungus is loose in PNG, there would be little hope to control it and many species could be lost forever. This is an important consideration for all biologists and tourists coming in and out of PNG.

Frogs

Collecting frogs is predominantly a nocturnal activity. A good torch is vitally important, and if possible a headtorch should be used. These leave the hands free for capturing frogs and writing field notes, and for steadying yourself in rough terrain. In addition, the angle of a headlight beam is such that the light from frog (and gecko) eyes is reflected back to you, an advantage that is lacking with hand-held torches. Frogs and geckos can then be collected in virtually any habitat by looking for their tell-tale eyeshine (light reflected off their retinas).

Frogs are often located by their vocal activity. Each frog species has a different call, and with practice it is possible to identify many common species by their specific calls alone. A wide range of frogs can be easily collected simply by tracking down frogs making different calls. Analysis of mating calls has become an important tool in frog taxonomy; whenever possible make a recording of up to ten calls from several frogs of each different species. Mating calls allow you to distinguish between frogs that look the same but are actually different species. Details of recording techniques are outlined in Heyer et al. 1994; only a brief outline is presented here.

You will need a small digital recorder, preferably with a good quality external microphone to enhance your recording. Get as close to the frog being recorded as possible (preferably within 20 cm) without disturbing it and aim the microphone in the direction of the frog. Do not shine your light on the frog until you have finished recording, as this may disturb it and make it stop calling. Patience is a necessary attribute when recording frogs because some only call every 5 or 10 minutes! When you have finished recording, collect the frog and record the air temperature (or water temperature if calling from in the water) at the spot where it was calling. Note this and all other details (your name, site,

date, time, weather conditions, substrate, species name, AND the frog's field catalogue number) on the tape (by speaking into the microphone) and in your field note book immediately after each frog call is recorded. The frog, with associated field number in its plastic bag, can then be processed with your other specimens, as outlined below.

REMEMBER: Frogs (and some reptiles) are often most active during or after rain and recording equipment must be kept dry-- a dry plastic bag will suffice in most cases for protection in rainy weather.

Frogs are commonly found along streams and rivers, and around swamps and pools (these need to be searched even if there are no frogs calling, as frogs may be there anyway). However, in New Guinea about half the species (all of the species in the family Microhylidae) do not breed in water, but lay their eggs on land or in the trees, and so can be very difficult to locate. Tracking down these species requires a great deal of patience!

Frogs that are collected (up to about 20 of each small species, fewer of large or common, widespread species) should be placed separately in plastic bags with a numbered tag included with each specimen. Notes on the locality, time, habitat, calling activity and tag number should be entered in a field notebook. The next morning these specimens can be processed (photographed, killed, fixed and preserved) and the field notes transcribed as a backup copy.

During the day frogs and reptiles can be found by turning over logs and rocks, raking the leaf litter on the forest floor, and by dip-netting in streams and swamps. Again, these techniques should be used in all available habitat types to maximize the diversity of species encountered. Frogs and some reptiles will die rapidly (and become relatively useless as specimens) if exposed to the sun or extreme heat, so care must be taken when transporting or storing live specimens during the day-- keep them cool and moist.

Tadpoles should be collected and a sample of each species should be immediately preserved in 10% formalin, and another sample preserved in ethanol. Try to rear some tadpoles through to metamorphosis so that they can be identified to their adult frog species. This can be done in large buckets or tubs. Tadpoles live in habitats as diverse as small temporary pools, large ponds and rivers, and in gushing torrents in mountain streams. They can easily be collected using a dip net that is swept through the water and over the substrate surface. Stream-dwelling tadpoles living in torrents can be collected by placing a net just downstream from loose rocks, which are turned to dislodge and sweep away the tadpoles sheltering underneath.

Reptiles

Nocturnal reptiles

Most reptiles will be collected during the day, but geckos, legless lizards and some snakes are nocturnal and so are more easily found at night.

Geckos, legless lizards and snakes can be collected in much the same way as frogs, although cloth bags are more suitable than plastic ones for storing the specimens until the next morning. Geckos can be found on trees, among rocks, on the forest floor, or on buildings where they are frequently attracted to lights. They have very bright eyeshine and so can often be detected over quite large distances. They can simply be picked up (be VERY careful of their delicate tails, which will fall off at the slightest pressure) and placed gently into a cloth bag with a specimen tag. During the day geckos, lizards and snakes can also be found sleeping under rocks and logs.

Legless lizards are lizards that closely resemble small snakes but are instead closely related to geckos (not snakes). They can easily be distinguished from snakes by the presence of small ear openings (lacking in snakes) and in having long (versus short) tails. They are harmless animals normally found at night as they search for prey and can be picked up by hand and placed straight into a plastic or cloth bag. It is best to treat them with the caution you afford snakes if you are unsure whether they are lizards or snakes.

Snakes

Because of the medical importance of some snakes, they have received more study than some other herpetofauna (e.g., Keogh et al. 1998). Snakes in New Guinea range from completely harmless to extremely dangerous and it is not always possible to tell the difference before it is captured. ***TREAT ALL SNAKES WITH CAUTION***, but not with blind fear! Most snakes can be collected using a long stick with an L-shaped head that can be used for pinning them down by the neck. They should be grasped firmly by the neck, just behind the head, so that they cannot bite you. Some snake handlers use thick gloves, but be aware that this makes your fingers less flexible. Most experienced snake handlers prefer the greater control and sensitivity of bare hands. Snakes can then be placed in a cloth bag or sack (pillow cases are good) and, if possible, cooled before they are handled again. Remember—they are cold-blooded and so cannot move as fast when they are cold. Snakes are found in a range of habitats, from streams and ponds to the forest floor and in the branches of small to large trees.

Because some snakes are venomous it is essential that you train with a qualified herpetologist before handling snakes. You must learn how to identify venomous snakes and you must learn proper handling techniques before handling ***any*** snake. When learning to work with birds and mammals, if you are occasionally bitten you are unlikely to suffer too much. However, a mistake when handling a snake can prove fatal. Be sure you have been well-trained and your trainer says it is OK before handling snakes of any kind. No one should attempt to learn how to handle snakes without professional supervision! There is a surprisingly substantial list of professional, highly-trained herpetologists who have been bitten by venomous snakes, many fatally. Never take the risks for granted or become complacent in your abilities.

Any field camp should be well provisioned with first aid materials. But if you are working with snakes, you should also be individually prepared for emergency treatment of snakebite. Immediate treatment can make the difference between life and death in the case of a venomous snake bite. If you are hours away from camp and unprepared, just getting back to camp for treatment could prove fatal. It is essential that any herpetologist working with snakes in PNG (at least in the lowlands where venomous species occur) carry emergency snake bite first aid. See the chapter on Safety for more details on first aid for snake bite. Even field workers not working with snakes should be prepared, particularly when any distance from the base camp.

Diurnal lizards

Most lizards are active during the day, and many are capable of escaping rapidly by running very fast or climbing high up a tree. Small lizards can be chased down and caught by hand, collected under logs, or stunned by a large rubber band. Rubber bands can be shot with accuracy after some practice, and lizards collected in this way are usually undamaged and make good specimens.

Many large lizards such as forest dragons (*Hypsilurus* spp.) and some goanas (*Varanus* spp.) are more at home in the trees than on the ground. Tree trunks and branches need to be searched for lizards hiding there. These animals are usually well-camouflaged, often being bright green to avoid detection amongst the foliage. Although they are not poisonous, large lizards can inflict a painful bite or scratches with their sharp claws, so they should be handled carefully. Grab them around the neck so that they are unable to twist around and bite you. Hold lizards in a large cloth bag. Some large lizards can be captured in live traps used for trapping mammals (e.g., Tomahawk traps). Use strong smelling baits like fish or slightly rotted meat. Traps need to be checked often because lizards often will struggle and injure themselves against the wire of a cage trap.

Freshwater tortoises (turtles)

Tortoises are the only group for which large nets are a useful collecting aid. They are most likely to

be collected by researchers using seine nets for fish. This group is poorly represented in New Guinea (Georges and Guarino 2005), and they are virtually absent (or at least unknown) from montane areas. Lowland streams, lakes and rivers should be sampled with seine nets, by dip-netting among vegetation and under logs, and if appropriate (i.e. if the water is clear and crocodiles are absent!) by snorkeling. Wherever they occur, tortoises are likely to be a regular food source for local people (Georges et al. 2006). The best way to inventory these animals may be to employ landowners to collect all of the species they are familiar with.

Preserving Specimens

The ultimate outcome of any inventory of frogs and reptiles will be a collection of well-preserved specimens and associated comprehensive field notes. In contrast to some other vertebrate groups (e.g. birds) that are reasonably well known in New Guinea, many herpetofauna specimens cannot be identified to species in the field. Undetermined specimens will require study in a museum with access to other specimens for comparison and primary taxonomic literature (books and journal papers). Indeed, it is quite likely that collections made during surveys of remote areas of New Guinea will contain a high proportion of undescribed species (new to science). It is therefore vital that voucher specimens are properly prepared for future study and identification. A job well-done in the field will help with the important job of identifying species or even naming species new to science!

Heyer et al. (1994) have outlined in detail methods for killing and preserving frogs; methods for reptiles are similar. Killing specimens in a humane manner can be difficult under field conditions. Specimens should never be dropped alive into preservatives (not only is this ethically indefensible even under arduous field conditions, but specimens treated in this manner become distorted and are therefore of limited use as voucher specimens). One method is simply to freeze the animals, but a freezer is rarely available in remote locations and frogs that are frozen make poor (softer) voucher specimens than those killed without freezing. Frogs are best killed by placing them in a jar with a small amount of chlorotone (chlorobutanol crystal dissolved in water). Reptiles should be injected in the body cavity with a dilute solution of Nembutal or chlorotone (instruction and practice will determine the amount needed for small and large reptiles).

As soon as they are dead, remove the heart and liver and place it directly into a vial containing 95% alcohol (or other approved tissue storage buffer). Include in the vial a tag (on waterproof paper) with the specimen field number written on it. These tissues are increasingly important for taxonomic studies and should be collected whenever possible (not only for herpetofauna, but also for birds, mammals, and fish). Contact with formalin makes tissues and specimens of all kinds useless for DNA studies, so this must be done ***BEFORE*** the specimens are fixed in formalin. Be sure not to use tools or vials that have been in contact with formalin when preparing tissue samples. Always clean your tools between specimens so as to avoid the risk of contaminating a DNA sample with the DNA of the previous specimen you prepared. Such contamination, once discovered, could make future researchers suspect the validity of any DNA specimen you have made. Such contamination undiscovered could confuse or even ruin the results of future DNA analyses.

Although tadpoles should be preserved in 10% formalin, for the reasons outlined above several tadpoles of each species should also be preserved in 95% ethanol (for DNA). When specimens are divided up this way remember to always make sure that each different vial has the same identifying field number.

It is a good idea to preserve several specimens of each species with its mouth open. This will permit examination of important features in the mouth at a later date. This must be done prior to fixation because fixation will set the jaws and body in their permanent position.

Simply pry open the mouth and place a small, clean stick in it to hold it open while it is fixed.

Fixation

A layer of gauze, tissue or foam should be laid out on the bottom of a plastic tray with a tight-fitting lid and soaked in 10% formalin. Specimens should be laid-out as described in Heyer et al (1994). The body should be straight and flat on the tray, and the toes spread so that details of the webbing and toes can be easily seen. Specimens can be pinned into position like this with one hand up and one hand down if there is a layer of foam at the bottom of the tray. In this way both top and bottom characters can be seen without moving the specimen. Reptiles should be laid out in a similar manner, but with the tail curved up toward the head so as to minimize the storage bulk. The associated field number (tag) should be placed on top of the specimen, and then a layer of formalin-soaked tissues placed over the top of the specimens. Pour in additional formalin so the specimens are left to sit in a shallow pool of this liquid. Large specimens will also need to be injected with formalin in the body cavity and large muscles.

Small specimens will be set within a few hours, large ones may take more than a day. Once they are set, or fixed (rigid), tie the specimen tag to the right rear leg and place the specimens in a storage drum containing 10% formalin for at least a few days. They should then be rinsed with water and transferred to and stored in 70% ethanol. Small specimens may best be grouped in plastic bags within the drum to minimize the chance of damage.

Locality data

During any species inventory in New Guinea a large amount of useful information and many specimens can be obtained from local villagers and landowners. If specimens are obtained from locals it is important to obtain as much information as possible about how they found the specimens, including precise locality, time, date, type of habitat, etc. Try to get local names for each species whenever possible, and include this information in your field notes. It may be advantageous to visit accessible sites with the locals, for example to record frog calls at sites where they have collected specimens. HOWEVER, locals should not be relied upon exclusively to obtain a comprehensive inventory of the herpetofauna (or of any other taxa). Their knowledge of the local fauna is likely to be far greater for species that are incorporated in their diet, and thus many small frogs and reptiles may be under-represented in any collections they make.

Standard Sampling

Standardized sampling of herpetofauna is becoming increasingly urgent as many species of amphibians in particular are going extinct worldwide. Because recent declines in amphibian populations across the globe have been documented and are definitely occurring in undisturbed as well as disturbed sites, a call for long-term monitoring of amphibian populations has been made by scientists and conservationists. There are many standard techniques to measure and monitor diversity of amphibians and reptiles. Among these, three different methods are most commonly employed in surveys: species inventories, plots and transects.

Species inventories are complete listings of herpetofauna at a site. They are usually a combination of informal 'general collecting' and the other two methods-- plots and transects. This is still largely a non-quantitative technique that accumulates data at single sites over long time periods. The end product is a species listing with natural history and ecological data associated with species. These lists are often hard to compare between sites and can only provide distributional data. Such lists, however, are often the only data that are available to scientists. By incorporating other quantitative methods, more meaningful analyses can be performed. Among the most common and easily employed of these methods are leaf litter plots and nocturnal transects.

The most effective size for leaf litter plots (or quadrats) in areas of rugged topography in New Guinea are 5 X 5 meters. This simple and easily-analysed method is suitable across a wide range of habitats and terrains.

The transect method most commonly employed by herpetologists is the Visual Encounter Survey (VES) transect. These are simply timed random walks usually made at night when most amphibians are active.

We will discuss the later two methods in more detail since they are so important to standard herpetofauna sampling.

Leaf litter plots

This is one method of quadrat sampling. Randomly selected locations are determined by following a random number (two or three digits) of strides along a pre-existing path (see Appendix 2 for a random number table). Then you determine the quadrat site by a second random number (two or three digits) of strides perpendicular to the path into the bush. Each quadrat is a 5 X 5 meter square, with each side being exactly at right angles to the adjacent sides. Fixed-size plots like this make good standard sampling units for statistical analysis. Each quadrat is worked by a team of four people-- one for each side of the plot. After the boundaries of the plot have been determined, the time of beginning the plot is recorded, and each person searches slowly through the leaf litter and ground detritus, sifting through the layers to locate frogs. A general sweep is conducted by each person on each side so that respective layers of leaf litter are brushed from inside the plot to the outside, from the front to behind. In this way no animals can escape without at least being seen. When frogs are located, they are captured and immediately transferred to a plastic bag. After everyone has met in the centre of the plot, the time of ending the plot is recorded, and data on the sex, SVL, location and mass of each frog captured are recorded. Each frog is released and all other habitat characterizations are completed (see the sample data sheet in Appendix 1).

Leaf litter quadrats are a useful technique when properly executed as they inventory terrestrial and fossorial[7] species at a site. Furthermore, quadrats serve as standard sampling units that are easily replicated and provide solid data on densities and relative abundances. Moreover, since each quadrat is randomly chosen and independent, statistical tests can be used to determine changes in species assemblages over time-- the goal of monitoring. Basic habitat characterization at each quadrat includes a variety of environmental descriptors which may influence the abundance and richness of the frog assemblage. These can be tested for correlations with the abundance data.

Nocturnal Visual Encounter Transects

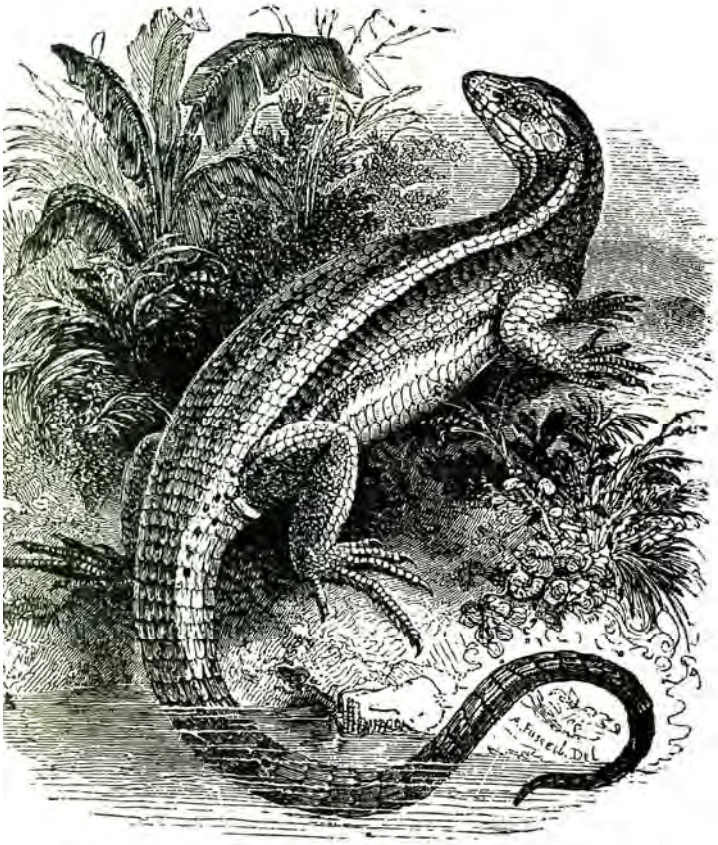
This is one type of visual encounter survey. Randomly selected transects (usually bush trails) are searched for animals for a prescribed period of time (one hour) at night. Each transect is worked by a team of two to four people—usually the same team working on the plots by day. One person is selected to record data, one to measure and hold captured frogs, and the other two have specific duties of locating frogs along the transect. The time of beginning the transect is recorded, and everyone searches slowly from ground level to approximately 3 meters above the forest floor to locate frogs; a headlamp or torch is used by each person. When a frog is located, it is captured, data are recorded on the identity, sex, SVL, location, and time of capture, and the frog is then released. After one hour of searching along the transect, the time is recorded and all other habitat and weather characterizations are completed. This is another highly effective technique to inventory and monitor virtually all species found at a site using a standardized sampling unit (the hour of searching).

[7] **fossorial**-- meaning something that lives underground

Safety

Collecting frogs and reptiles is often a nocturnal occupation, so it is worthwhile to re-emphasize a few safety points.

- Never work alone at night, especially in dangerous situations such as steep streams. One fall off a slippery rock or path can lead to disaster.
- Always check potential sites for night surveys during the day beforehand. In this way dangers such as holes or cliffs, which might not be visible at night, can be assessed.
- Always tell someone where you are going to be working so that if an accident occurs you can be found.
- Do not handle snakes unless you have been properly trained in handling techniques and identification of venomous species.



CHAPTER 9: Insects

Introduction

Insects are an extremely diverse group in Papua New Guinea. There are no good estimates of how many species are found in the country, but there are estimated to be over 25,000 species of New Guinea beetles alone (Coleoptera) (Gressitt and Hornabrook 1977). That is roughly 10% of the known beetles of the world! In PNG we know of over 817 species of butterfly (Parsons 1991), more than twice the number known from all of Europe. And there are undoubtedly many new species to be discovered in PNG. It is extremely unlikely there are any undescribed species of butterflies in Europe! Even beginning entomologists have the potential to make very significant additions to the world's knowledge of insect life in New Guinea.

Because insects are so diverse, it is impossible for an entomologist to master their identification the way vertebrates can be learned (compare 708 species of birds in PNG versus over 25,000 species of beetles alone). Therefore, entomologists should first learn how to identify the major orders of insects found in PNG. If you wish to develop greater expertise, it would be good to concentrate on the taxa within one of these Orders. The great diversity of insects, the ease of sampling them, their ubiquity, and their ecological specializations make them particularly good candidates for ecological monitoring. One can obtain much larger sample sizes of insects in a relatively small area than is possible with most vertebrates. Furthermore, because insects occupy many different habitats or environments they can be used as indicators for many different environments. They can be used to indicate secondary growth, undisturbed forest, swamps, savannas, etc. They can also be sensitive bio-indicators, revealing aspects of the environment that might not be apparent to our eyes.

Aquatic insects are a particularly important group for study because they are often used as bio-indicators, telling us about water quality, e.g., if a stream is being polluted by a mine or logging. Since people directly rely on clean freshwater resources, aquatic bio-indicators can be essential in the absence of expensive water testing. Also, since streams present a discrete, relatively easily sampled habitat, it is easier to thoroughly study aquatic insects than many terrestrial habitats. PNG has more literature on aquatic insects than on many other groups (Dudgeon 1994, Yule and Pearson 1996, Balke 2001, Polhemus and Polhemus 2002, Balke et al. 2004).

Insects are tremendously important economically. Most of the plants in PNG are pollinated by insects, including food plants that we humans eat. Without adequate insect pollinators, fruits and seeds are not produced--leading to the reproductive failure of most plants and causing animals that feed on fruits or seeds to starve. Insects are major decomposers of dead organic matter and play a crucial role in nutrient cycles in most ecosystems. Insects are often the link in the food web between plants (primary producers) and larger animals like birds and

mammals. Without insects, life as we know it in PNG, and the world, would be radically different. Some insects are extremely important in terms of human health because they transmit diseases such as malaria (e.g., Hii et al. 1997, Foley et al. 1998). Insects also kill many plants and seeds-- thus modifying the population structure of plant communities. Plant communities often determine what other animals live in an area. The interactions between all these different organisms are truly complex and make fascinating study (e.g., Bassett 1999, Bassett and Novotny 1999, Novotny et al. 2004, Lewinsohn et al. 2005, Novotny et al. 2005, Pokon et al. 2005). Learning about these interactions can help us understand the position we humans should and should not play in the complicated balance that is the natural world.

Standardized Sampling

It is important when trying to make comparative studies of insects between two sites to use identical methods at both sites (or at least to make your methods as similar as possible).

Light Traps

One insect sampling method that has been applied fairly widely in PNG is to inventory moths attracted to lights. Moth inventories can be compared to identify areas of greater or lesser moth diversity and this is sometimes considered a good proxy for overall biodiversity.

Moths (Lepidoptera) are a good group to census because they are diverse, cosmopolitan in PNG (meaning they are found everywhere), they are easily sampled and captured, and specimens can be prepared and identified without too much trouble back in the laboratory.

Moths are collected by making a collecting station somewhere at the survey site, usually located on a prominent hilltop or by the edge of a large river-- anywhere with a wide vista so moths can see the collecting station from far away. The collecting station consists of several white sheets hung vertically with two large mercury-vapor lamps and 6 ultra-violet lamps (black lamps) in front of the sheets. The lamps are driven by a small, portable gas-powered generator. At night the lamps are lit and moths are attracted from a large distance to the brightly shining white sheets. The insect biologists then simply collect the moths that come and land on the sheets. This is repeated for several nights until roughly 4000 moths have been collected. It is desirable when collecting data like this to record which moths are captured which night, so you have a standard sampling unit (say 6 hours of collecting per night).

Sticky Traps

Sticky traps are pieces of paper of a fixed size covered with a sticky substance (like Tanglefoot). When insects touch the trap they become stuck and the entomologist can check the traps regularly to collect the insects. Sticky traps can be brightly coloured to attract day-flying insects, scented to attract certain kinds of insects, or placed near baits or in flowering trees. The size of the sticky trap can be controlled so you have a standardized sampling unit. It is necessary to have a solvent that will allow you to remove the captured insects to make specimens.

Pitfall Traps

Pitfall traps can be used to sample leaf litter insects as well as other types of leaf litter fauna. A good way to make insect pitfall traps is to dig a hole so a plastic drinking cup (about 500 ml) fits in the hole with the lip flush to the surface of the ground. Nest one cup inside another and put it in the hole, pushing the litter up so it covers the lip of the cup so that insects can walk right into the cup. Lift the inner cup out of the outer cup and discard any litter that might have fallen into it when setting up your trap. Then put a mixture of water and detergent in the bottom of the cup and nest it back inside the outer cup. Lay out a line of such cups, say one every five meters along a transect. You can check them early each morning to get insects active by night and just before dusk to get insects active by day. When you check them simply lift out the inner cup that

contains the fluid, pour the fluid through a sieve (like a tea strainer) into another cup and put that cup back in the outer cup in the hole. Collect the insects from the strainer into a separate container, label it and take it back to the lab for sorting later on. You can suspend baits just over each pitfall to attract certain kinds of insects. Baits can be rotting meat, dung, fruit, etc. Anything that might attract the insects you are interested in. Be sure to record what bait is used for each pitfall trap sample.

Flight Interceptors

There are numerous kinds of flight interceptor traps. A simple one is a piece of mosquito netting about 1.5 m long by 35 cm high suspended just above the ground. Beneath the cloth put trays containing water with detergent. Some flying insects will hit the cloth and drop down into the trays where they drown. This method, like all methods, will not sample all the insects in an area, or even all those that will fly into the cloth (some climb up and over or bounce off and fly away). However, it does give us a standard sampling unit that can be repeated often.

Other sampling methods

There are many, many other sampling methods, such as fogging tree canopies with insecticide. Some insects can be surveyed visually, just by looking for them, e.g. Odonates[8] (Oppel 2006a, Oppel 2006b). Because of the great diversity of insects and their wide array of habits and habitats, there are too many potential sampling methods to even begin to describe here. In fact, if you develop just a little proficiency in a particular insect group, you will probably be able to design your own sampling methodology. For example some entomologists study dung beetles by laying out baits comprised of their own dung, others allow mosquitoes to feed on their skin and collect the mosquitoes with a mini vacuum cleaner! The important thing to consider is how to make your sampling method quantitative.

[8] Odonata include dragonflies and damselflies.

Preservation and Labeling

The many kinds of insects have different methods for proper specimen preparation. Many species can be pinned and dried. Special insect pins should be used for this and they come in various diameters. Some are quite thin and with practice you can learn to pin tiny insects. Insect pins are usually made of a material, like stainless steel, that will not rust easily in tropical humidity. Different taxa have different ways of being pinned. Usually for larger insects the pin is inserted on one side of the midline, so as not to potentially cover any characters that are along the midline axis. Some large insects, such as katydids, need to be "gutted" before they are dried. Make an incision along one side of the abdomen and with forceps pull the guts out. Larger insects might need to have a bit of cotton placed back in the abdomen to make them look lifelike again.

Very small and delicate insects are often glued to the tip of a small triangle of stiff archival paper, and the pin is then inserted through the triangle.

Lepidoptera are usually pinned with their wings spread in certain ways on a spreading board. Larger Orthoptera[9] are often positioned in specific ways with their legs and antennae held in place with many pins until they dry. Sometimes a few individuals of winged species are pinned with one or both wing extended (e.g. winged beetles) while most specimens are pinned with the wings closed under the carapace.

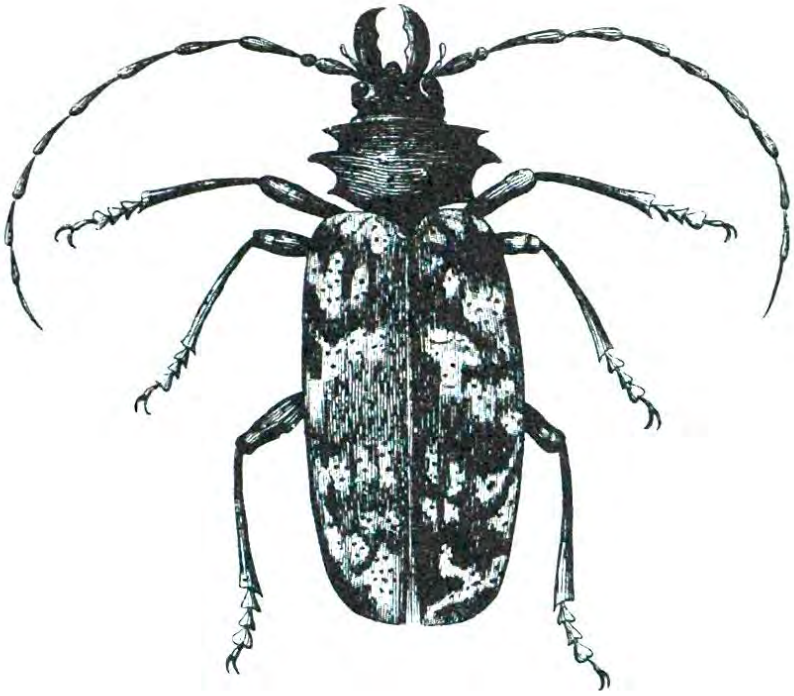
Some insects are more easily stored in ethanol in the field, especially particularly soft insects like caterpillars or termites. If necessary, insects can be stored in ethanol in the field and then later pinned and dried back in the laboratory. Putting insects in ethanol usually destroys colour patterns whereas drying specimens when fresh will usually preserve colour patterns.

As with all other specimens, it is crucial to ensure the specimens and collection data stay together. Eventually pinned insects are given small tags that list the basic collecting data--

[9] Orthoptera include crickets, grasshoppers, katydids, and walking sticks.

location, date and collector minimally. Many insects collected on the same day in the field at one site can be put together in an envelope with one tag. It is usually not practical to tag individual insects in the field, so we collect those with common tag information in envelopes or vials with a single tag. We call such samples "lots." Usually back in the lab we sort the "lots" and properly prepare, mount and label these insects. It is important to work as efficiently as possible in the field to optimize your time to collect specimens. When possible, tasks that can safely be postponed to later in a lab should be postponed. This way you can optimize your productivity in the field, as measured by how many specimens you collect. So long as you keep the data with the specimens, more is better!

But a larger problem for insect sampling is that there are so many insect species and so very few people capable of identifying them (other than Lepidoptera and some Coleoptera which are fairly-well known). Thus, although insects are admirably suited for sampling and as indicators of habitat, they are difficult to use in surveys because of the paucity of trained insect taxonomists. It is possible to collect many more specimens in a short period of time than you will likely be able to identify in months, even with the help of an expert entomologist. This presents a challenge and an opportunity to young entomologists in PNG. The determined student can, with a good deal of work, develop expertise in entomology that will enable her or him to become an outstanding expert globally on a particular insect group. We have included this short and inadequate chapter on insects as a reminder to students that there is a tremendous amount of work that needs to be done in entomology! The serious student can create a unique niche for him/herself by mastering the taxonomy of a small subset of PNG's incredibly diverse insect fauna.



CHAPTER 10: Introduction to Sampling and Experimental Design

Good decisions depend upon good information. The quality and reliability of information (data) depend upon the techniques used to obtain it. This chapter introduces several basic concepts of scientific sampling that are broadly applicable to all groups of organisms and field questions. These concepts and entities are: sampling and sampling design, standard sampling units, replication, consistent application of methods and hypothesis testing.

Sampling

If we want to know what animals are in a large area we cannot always search the entire area thoroughly. For example, if we wanted to make a list of the mammals found in Simbu Province it would be very difficult to go out and thoroughly search all of Simbu Province. Therefore it is necessary to sample some, but not all, of Simbu Province. Many things will determine how you sample an area; there is not one simple and correct way to sample. There are many approaches to sampling that are correct and many that are incorrect. One of the greatest skills you need as a scientist when undertaking field studies or surveys is to determine the best way to sample a population. A population is simply the total group you are interested in, in this example, the mammals of Simbu Province. If we want to learn about the whole population, we sample a sub-group of the population and then use that information to make estimates or approximations of the total population. For example, we could sample the mammals found at five elevations in Simbu Province and use these samples as indicators or predictors of the population of all mammals found in Simbu Province.

In the example above, notice that we sampled the population at five different elevations. ***The value of a sample depends upon how representative it is for the total population.*** Ideally, in this example we would sample at elevations spanning the range found in Simbu Province (300-3000 meters a.s.l.). If we had sampled at five elevations, but these were all between 1000 and 2000 meters, we would not have a good sample for all of Simbu Province. We might have a very good sample for a district in Simbu Province, but not for the entire Province. Thus, you can see how the sampling design is dependent upon what question you are asking-- that is, what population you wish to sample. Good sampling is specifically designed for the question and the population under question. The first step to proper sampling is to explicitly define what your sample population is—all mammals of a district, province, nation or continent? Or only those within 10 km of a particular village?

You will learn how to analyse a problem and design a sampling protocol that will give you the most reliable answer. You can use this skill in any job you have. For example, say you are responsible for purchasing office supplies for your business and can choose from four stores in Port Moresby. If you went to all of the stores and just looked at the price of paper, or only looked at the price-list for two of the four stores, you would not have sampled the population properly. A better

sampling procedure would be to compare the prices of the ten office supplies you purchase the most and see which store has the overall lowest prices for these items. ***Proper sampling design is a skill you can apply to whatever job you have.*** We are focusing on biological sampling, but the general ideas are the same for every occupation.

The first step in designing how to sample a population is to clearly identify the question or questions you are going to ask of the sample data. Then you must design a plan that will best answer your question/s and which is feasible given the time available, budget and your skills. For example, if we wish to learn what trees are growing on a proposed timber concession in Central Province we might design one sort of sampling design. However, if we want to learn how many trees of a certain genus are on that land, e.g., *Pometia* spp., we would design our sampling differently to census *Pometia* spp. rather than all species.

Sampling Design

Plenty of thought should go into designing your sampling technique ***before*** you begin sampling. This is one reason it is important to write a proposal, or at least a research protocol, before beginning a project. Where, when, how, how much, etc., all must be established before starting fieldwork. Once you are in the field, you do not want to waste time and effort deciding what you are going to do. Of course you might have to adapt your sampling protocol to field conditions if you run into problems.

When you are designing a sampling protocol carefully consider all of the following factors:

1. What question/s do you expect to answer with the sample?

What is the goal for your sample? You must identify what question you want to answer with your sample. Until you have explicitly done this, you cannot properly design your sampling procedure. Identify your goal, then design the best way to meet the goal. Too often people begin by designing their methods and then try to fit their goals to them. This is backwards, but many people do it, even very experienced scientists. For example, if you just want to know "Are tree kangaroos found in the Torricelli Mountains?" you might be able to answer this question by examining the literature or a museum collection. If you want to know "What is the density of tree kangaroos in the Torricelli Mountains?" then you will have to design a way to sample the Torricelli Mountains and go there to do it. The first question might be answered with an hour of work and very little cost; the second might take weeks and cost thousands of Kina. ***EXPLICITLY STATING YOUR QUESTION IS THE ESSENTIAL FIRST STEP OF ANY RESEARCH PROJECT!!***

2. What is the expected density of the organisms you want to sample?

The actual counting, measuring or enumeration usually is very time-consuming because proper sampling requires replication (see below). You must consider how much time you expect it will take to do this when deciding your sampling area and design. This requires some knowledge about the organisms you will be studying. For example you might not want to count all the ants on a hectare, but counting all the trees ≥ 10 cm DBH on a hectare might not be so difficult. Your knowledge of the expected numbers of ants, trees, or cuscus will help you decide the feasible area you should sample. If you start a sample, but do not have time to finish the sample, you have wasted your time because there is very little you can do scientifically with an incomplete sample.

If you do not have sufficient knowledge of the population you will sample, you should conduct a pilot study (short practice study) to help you design the final sampling protocol. There are quantitative ways to predict just how much sampling is required to answer a specific question for a specific population; if you have some initial data you can use that to determine how much more sampling you will need. Generally, it is best to sample as much as you can.

If you sample too much, it only strengthens your data, but if you do not sample enough, your data might be useless. But if you over-sample you can waste time and money for data that does not strengthen your conclusions—there is a trade-off.

3. How much time do you have to obtain the sample?

Given what you know about the expected density in the sample, plan your time accordingly. Usually we have a known, limited amount of time for fieldwork so you must plan your sampling to fit in this time. However, we often forget there are other time-consuming demands for which you must also plan. Sampling is pointless if you do not have the time to compile and analyse the data and communicate the results. When designing a sampling program it is crucial to allow the time needed for sorting specimens, organizing your field data, entering it into a computer, analysing, and writing reports. These are all essential parts of a field project that are often forgotten or ignored by even the best scientists. A published, small study is much better than an unpublished huge study!

4. How much money do you have available to obtain the sample?

Just as your time can limit how much you should sample, so will your budget and resources. It makes no sense to plan to tag 5000 plants if you do not have a budget to buy 5000 plant tags. Plan your financial budget ahead of time, just as you plan your time schedule. If you intend to sample at two locations, say Varirata and Mount Michael, you might have to consider that it will be more expensive to work on Mount Michael. It is not important that you spend your money equally at two sites, but it is crucial that your resulting samples be comparable. The same might apply if you were sampling over time. It will cost more initially to set up a permanent study plot, but it will cost less when you come back later to re-sample it. Many good scientists fail to plan their projects well and end-up running out of money and are unable to finish otherwise good projects. Don't let this happen to you-- just a little cautious planning can help you avoid all sorts of problems.

5. Can you or others repeat the same sample at the same or other locations?

One of the criteria of good science is that a study be repeatable and verifiable. You must have a design that others can repeat. This means, among other things, leaving out subjective judgments, e.g., "I sampled moths where I thought the habitat was optimal." Always assume someone will someday want to repeat what you have done.

Usually when we sample to census populations we are comparing different sites, e.g., logged versus unlogged forest, organic versus chemically-treated gardens. This demands we are able to repeat the sampling as identically as possible in different sites, and usually at different times. Often this requires collaboration with others, so they must be able to accurately replicate what you do.

6. What is the biology of the organisms you will sample?

Every species is different, so what might work well with one species might not work at all with another. It helps to have knowledge of what you will be working with, or knowledge of closely-related species. Seasonal behaviour could alter your sample results-- many birds in PNG migrate, so sampling at different times of year could yield different results. You need some knowledge about when, where and how to sample your organism(s). This is where biological training is important. You can gain the necessary knowledge for your taxa from the literature, personal experience or communication with others who have experience. If adequate knowledge cannot be obtained, you need to do some pilot studies.

7. Is there flexibility in case of unforeseen problems, and will you be able to adapt to new circumstances?

Research rarely goes according to plan. No matter how well you have planned you will

face unforeseen problems. But note: if you plan poorly, you are certain to face even larger unforeseen problems. Often it is necessary to change your plans in the field. Perhaps you will find the organism you want to study is rarer than you thought, so you might have to make more or larger plots. On the other hand, you might find it is more common than you thought, so you can save time by using smaller plots or transects. Maybe it will be something simple like you have not brought enough aluminium tags and are going to run out, so instead of running out you cut your tags in half and just use smaller tags. Many problems can be overcome with a little ingenuity. It is important that you do not give up when problems arise. Stay calm, think about a solution, talk with your co-workers and seek their ideas. Other people might see solutions to problems you think are unsolvable.

Remember, ***field time is extremely precious.*** If you have gone to the effort to get into the field, don't give up!! When you read other people's science it might seem like things worked well for them, but that is just because no one ever writes about the problems they had to solve. You will have to solve problems, everyone does. Just be prepared; stay calm, and you'll be surprised how much you can accomplish even when it seems that all your initial plans have been upset!

8. What are the landowner and other logistical considerations?

In PNG it is important to consider landowners in all research. One example of this is obvious when you think about sampling through time. If you want to study how something changes over ten years, like the number of trees per hectare, then you will need to be confident that you can re-sample your plot for ten years. This means you will need to maintain good relations with the landowners. If you treat them unfairly they might not let you return and your project will fail. Some landowners are more supportive of research than others. However, the rights of landowners in PNG are stronger than in much of the world, so foreign scientists often are not aware of these considerations. It is important for you, if you are collaborating with foreign scientists, to make sure they do not make mistakes out of ignorance. For example, a foreign scientist might try to start a project in PNG not realizing he needs landowner permission and this could lead to trouble or a compensation claim. If you are collaborating with a foreign scientist, it might be important for you to make sure they understand landowner issues unknown to them in their own nation.

Standard sampling units

A standard sampling unit (SSU) is a group of observations or data collected by a discrete, clearly-defined method that is readily repeated identically many times (see replication). The SSU will usually be the unit that determines your sample size (N) in a statistical test. If you sample ten plots, where the plot is the SSU, then you perform statistical tests with N=10. As you will see when we get to statistics, you cannot statistically compare one thing to another where you do not have multiple SSUs. For example, if you wanted to compare the heights of women from Manus to those from Bougainville, you could not have one woman from each island and conclude one island produces taller women. If you sampled 100 women from each island, then you have replicated measurements (100 SSUs from each island) and then you could make a statistical comparison.

The SSU must be defined in advance when you design your study. Before you begin any project or submit a proposal, you should be very clear about what your SSU will be. In other words, you must define your sample (like a plot) in a fixed way that can be repeated. For example, you cannot sample plants on plots and get any meaningful data that can be properly analysed if your plots are not all the same size and shape. You cannot statistically compare the number of trees on a 100m^2 plot with the number on a 225 m^2 plot (although you could use a subset of the 225 m^2 plot that was 100m^2).

Standard sampling units are necessary for all of the survey, census and sampling techniques in this manual and any others you will learn. You cannot compare data from leaf litter plots with visual encounter surveys. You can, however, compare leaf litter plots from one site to leaf litter plots from another site if they use the same plot design. If you carefully design your sampling program, you will have SSUs that will be comparable or can be adapted for comparison to other data sets. ***Your sampling units must be consistent within your study.*** For example, if your standard sampling unit is trap nights (the number of traps set per night), these should all be the same kind of trap to be properly consistent. You cannot combine trap nights using small rat traps with trap nights using large cuscus traps.

This might sound simple, but you would be surprised how many good scientists conduct studies without specifying good standardized sample units. Do not make this mistake with your work. ***Before you begin a survey write down what your sample units will be and carefully think about whether they are truly identical units.*** Read other studies and examine other data sets to see how you can collect data in a way that will be meaningful for your objectives *and* produce data you can compare to other sites. If most people census trees ≥ 10 cm DBH on 20 X 500 m hectare plots, you want to use this same standard measure so you can compare your results to their studies.

Replication

Replication simply means you take numerous copies, or replicates, of your standard sampling unit. Mathematical analysis of your data (statistics) requires replicates of your data and generally the more replicates you have, the better. For example, let's say we want to learn something about the number of rats in a forest. If we set a single trap for one night (one trap night) we have a standard sampling unit, but only one (in science we write this as N=1). If we did not catch a rat that night would we conclude that there were no rats at all in the forest? Of course not. If we set two traps for one night (N=2), and caught 2 rats (100% capture rate), would we conclude that whenever you set a trap in that forest you would always capture a rat? Of course not. We cannot draw conclusions until N, the sample size or number of standardized sampling units, is reasonably large. If you ran 100 traps for 7 nights (N=700 trap nights) and caught 10 rats each night, you might feel a little more confident in saying you have a 10% capture rate (10/100 = 10%) because you got the same results over 7 different nights. Statistics simply quantify what we feel intuitively. Statistics tell us how much confidence we can place on a conclusion based on how much sampling we did.

Consistency in measurements

During field training courses students usually learn how to use a number of measuring devices: DBH tapes, transect tapes, calipers, pesola scales, wing rulers, etc. You might already be familiar with many of these. However, it is not enough to know how to use these instruments, you must also learn how to make standard, consistent measurements. You will be measuring many things and the replicated measurements (your sample or N) must all be made in a consistent fashion. This means each time you make a measurement of an individual or a sampling unit you must make the measurement exactly in the same way you made the measurement before. For example, if you wanted to measure the height of people on your training course you would want to make sure everyone was standing up straight and that everyone was not wearing shoes. If you did not strive to make your measurements consistently, they would not really reflect the true differences in the height of your classmates. Someone might seem taller because they had shoes on and stood up straight whereas someone else seemed shorter because they slouched and were bare-footed.

The above example may seem apparent, but many biological field measurements are not so obvious. You will learn how to measure the wings of birds, the ears of rats, the diameters of

trees and much more. To make such measurements you must learn the standard techniques widely accepted among biologists. You must learn how to identify the standard points where such measurements are taken and practice making them so you always take consistent measurements.

As you progress in science you will someday design your own projects. As you learn different kinds of measurements in your courses and career, think about why the measurements are taken the way they are. Measurements need to be from unambiguous starting and ending points, be easily and accurately replicated, and should have some biological significance.

Bias in sampling

Imagine that the Department of Environment and Conservation (DEC) is monitoring the biological communities at a site near a large Timber Rights Purchase area. The first survey of the site is done by a UPNG graduate who is an expert on PNG birds. This biologist might be very attuned to the bird communities but not to other taxonomic groups. His/her report might reflect this by listing many bird species, but not many non-bird species. In contrast, suppose that for the next survey of the same site the bird expert is not available and DEC sends another person who is an expert in dung beetles. This second biologist would probably be more attuned to the beetle fauna than to the birds, and his/her report would probably include an extensive list of the beetles, but only the common species of birds. Now imagine that the first survey was done before logging in the TRP and the second was done after logging. The resource manager for the TRP wants to compare the two reports in order to understand if logging in the TRP has influenced the species composition at the nearby site. The manager is faced with a problem. If the reports are accurate, it appears that the number of bird species at the site has declined while the number of dung beetle species has increased. In fact, as we have seen, the difference in the two appraisals of the site were actually due to the ***bias*** of the two biologists, and not necessarily because logging has changed the species richness within each taxon. Minimizing such biases is one of the greatest challenges for field biologists.

Because most studies are conducted in slightly different ways by different people, the prospect for biased results is great. To minimize this bias, field biologists try to use the same standard methods whenever they collect samples.

When biologists assemble species lists for a site, they often survey in a variety of habitats, and do not confine themselves to a single sample area. By this procedure they generate large species lists, but unless the biologists carefully describe the size and characteristics of the areas they survey, their species lists are difficult to compare with those from other sites. If the surveys at different sites are conducted on plots of the same size and if those plots are randomly located, data among them can be readily compared. To avoid bias due to deliberate placement, plots are usually randomly situated. For example, treefall gaps can be nasty places to work due to the rattans (*Calamus*) that grow there; a biologist might deliberately place plots so he or she avoids having to work in these inhospitable tangles, thereby generating a bias in the data. The biased data would suggest *Calamus* vines are rarer than they actually are if the plots avoid gaps. One way to properly choose study plots is to create a map of the entire potential region and divide it into numbered plot-sized sub-areas. One of these numbers is selected from a random numbers table (see Appendix 2), and that becomes the place you position a plot. The important thing to remember is: ***always design your sampling to minimize potential observer bias; use a random number table whenever possible when decisions that could create bias need to be made.***

Experimental Design

Experimental design sounds a lot more technical and tricky than it actually is. You use basics of experimental design every day although you might not recognize it. For example, if you want to learn if a handsome or pretty classmate likes

you, you might try to come up with a good "experiment" to find this out. You might decide on an "experiment" where you ask the student if they would like to study with you, or go to town with you. We design experiments all the time-- anytime we want to find out some sort of new knowledge. Is the water hot enough for tea? A bad experimental design might be to dip your finger deeply in the water: "Ouch, yes it is ready, but now I'm burned." A better design might be to look at the water and see the bubbles on the bottom of the pot: "Yes, it is beginning to boil (and I'm not burned)."

Experiments are not just things scientists in white lab jackets do inside laboratories. With a little knowledge of the situation-- the physics of heat transfer or what your attractive classmate likes to do-- you could design the best "experiment." The same is true with biology. With some fundamental knowledge about the things you want to learn about (your basic biology) and some design tools (this course), you will be prepared to go out and discover new things. Hopefully without getting burned!

Hypothesis testing

Like "experimental design," hypothesis testing sounds a bit technical and not something you do very often. But indeed, we do it all the time-- anytime we formulate an idea about something that is happening and try to find out if it is true. In the previous example we might have formed the hypothesis that our attractive colleague does or does not like us; we decide to test this hypothesis by seeing if s/he wants to spend some time with us. This is a reasonable design to test our hypothesis. But it can still be tricky. If for example, we asked him/her to go fishing on our uncle's boat, we might have been turned down because s/he gets seasick; we might mistakenly interpret this as dislike. It was a bad experimental design: we tested the hypothesis that the person likes to fish on a boat, not whether they wanted to be with us.

Hypothesis testing means that we clearly and unambiguously create a question or a series of questions that have discrete answers. We then conduct an experiment or use observational data to find the answers and THEN we can draw conclusions about our hypothesis. The fishing example was not a good design because we confused several hypotheses (attraction to you and attraction to being on a boat). You might have solved this with a design where you then asked your attractive classmate if s/he would rather go get some food with you, go to the library with you, go to a shop with you, visit the museum with you, go watch television with you, visit some friends with you, etc. After being told "no" to all these things, you might begin to feel you've answered the hypothesis and can conclude that the person does not really want to spend any time with you. At this point we usually revise our opinion and decide that the other student is not that attractive after all! Good experimental design does not mean that we always get the answer we desire.

A hypothesis is something we think might be happening, something we think might be the cause of something, or even something we think might be related to something else. We can design experiments to test hypotheses or we can use observational data to test hypotheses. In either case, we test to see if the data support our hypothesis or not. We can test questions in the field or in the lab. The skills of good design and analysis are applicable everywhere.

However, before we can begin to design any sort of project, we must make sure we have a good, well-defined hypothesis. This is the essential trick to doing good science. Although we discuss this at length in the chapters on grant proposals and statistics, here we want to introduce you to the importance of a good hypothesis. A good hypothesis is:

- **Unambiguous.** It is generally difficult to simultaneously test multiple hypotheses. So you want to refine how you word your hypothesis so that it is as close as possible to one single hypothesis and is not confused with another hypothesis. For example, you want to learn if someone wants to spend time

with you, not whether they like fishing from a boat.

- **Explicit and clear.** Once you have focused on a single hypothesis, you need to define it precisely; sloppy language will lead to a sloppy design. Even if in your mind you know what you want to test, you must state it clearly. For example, you wanted to know if the water was hot enough to brew tea, not just whether it was "hot," a term that is relative.
- **Testable.** It is not science to make hypotheses that are not testable. If the fishing is poor you might blame the spirits of the ocean, but unless you have some way of testing to see if the spirits are responsible, it is a poor hypothesis and is beyond the realm of science.

Design of controlled experiments

Usually when people talk about scientific experiments they are referring to controlled experiments. Controlled experiments are the ideal in experimental design, but as field biologists we sometimes must compromise a bit because many variables in the field cannot be controlled. For example, we might be able to control the temperature and humidity in a lab or greenhouse environment, but in the forest controlling the weather is not so easy. By control, we mean we hold some variables constant that might affect the outcome of the experiment. The safest way to do this is to compare two groups (or samples) that differ only by the factor that is part of our hypothesis-- remember that a good hypothesis has only one, unambiguous, explicit and testable factor. ***In a controlled experiment we hold all the other variables constant and vary only the one we have designed the experiment to test.***

We conduct controlled experiments when we manipulate a variable in one population (the treatment group) and compare the result with another, un-manipulated population (the control group). For example, suppose we have a hypothesis that worms in the soil promote plant growth. Good start, but it needs to be less ambiguous and more precise. Worms of a particular species promote the stem growth rate (height) of a certain species of plant. Better. Now we design a controlled experiment. We make a control group and a treatment group-- both groups use seeds of the same size of the same species from the same parent plant (we are controlling effects of seed reserves, species and genetic effects). In twenty pots we put a fixed amount of identical soil (we control for effects of soil content). We put the twenty pots together in a greenhouse where temperature, humidity, light and water for all pots are identical (we control for environmental factors). In each pot we place one seed. Lastly in ten of the pots, randomly selected, we place five worms of equal size (we control for number and size of worms) and no worms in the other ten pots. Then we measure the height of the seedlings at the same time every day (we control for time of day effects). You can see that we have made every effort to have a design that varied by only one variable, the presence of worms. Later with our statistics we will see that we can compare the two samples mathematically, with worms vs. without worms, to learn if our initial hypothesis is supported or not.

It is easiest to set up controls with laboratory experiments, but as field biologists we will do experiments with controls too. Even in the laboratory there can be factors that might pose complications. For example, what if the pots were too small to support the worms and they died? A difference in growth in the plants could have been due to the nutrients released into the soil by the decaying worms, not by the effects of the live worms—this was not the hypothesis we wished to test. In the field we might try to set up an experiment to test the effects of worms without the use of pots. Can you think of a way to do this? It would not be easy. Often the best biological experiments have both field and laboratory components that complement each other. Each has limitations—lab experiments are not in natural ecosystems and so might not reflect biological reality, but field experiments are

difficult to control. If we conduct both, and both support our hypothesis, our result is stronger.

Hypothesis testing with surveys

On surveys and inventories we are more concerned with observational science than experimental science. Generally on surveys we are not conducting experiments where we manipulate a variable in one population (the treatment group) and compare the result with another, un-manipulated population (the control group). Experiments are usually designed to test a hypothesis—a proposed explanation for something we thing is occurring. But we can also use observational data to test hypotheses—to see if the data support the hypothesis or not. For example, we could make the hypothesis that lowland forests have more rattan (*Calamus* spp.) than highland forests. We could test the hypothesis by comparing vegetation plots from both altitudes. This is an example of hypothesis testing using observational data. Note that we did not have true treatment and control groups. We could not manipulate the forest by changing its elevation (e.g., magically raising the lowland forest into the mountains and seeing how *Calamus* responds)!

Much of survey work is designed to test hypotheses, although this might not be immediately apparent. Basically any survey is testing the hypothesis that the _____ (frogs, birds, trees, etc.) at one site are different, or not different, from the _____ (frogs, birds, trees, etc.) at another site. So, although much of survey work is purely descriptive, it is intended for use in hypothesis testing. Consequently, we need to collect our survey data in a consistent, scientifically rigorous fashion; otherwise we will not be able to statistically test hypotheses.

Goura Albertisii.

CHAPTER 11: Introduction to Data Analysis

Introduction

A good proposal will include a description of how the data will be analysed. So to begin analysing your data do the analyses described in your proposal. However, you should also analyse your data in other ways if you think it might reveal interesting results. As you collect you data you might see emerging patterns, correlations, or trends that should be pursued, even if these were not described in the original proposal. One of the beauties of biological research is that you can never fully predict what an investigation will reveal. In fact, if the results of a proposed study are clear and guaranteed, there probably is little reason to do the study! You want to collect data that will tell you something new. Often this is not apparent until you "play" with the data and search for new meanings the data can reveal.

Analysing data is fun. There is no right or wrong in your "playing" with the data. The right or wrong only comes once you try to communicate your results to someone else. Everyone makes many analyses that are worthless, incorrect, or meaningless on the path to their earth-shattering result. You don't report all your dead-end attempts, just the earth-shattering ones. An artist does not display all of their preparatory sketches, just the final, finished painting. An architect does not give the customer all the calculations and draft diagrams, just the finished diagram and specifications. Biological research is the same: try whatever analyses you think might prove interesting, but report only the most important and valid results.

Lots of people are fond of saying "information is power." What these people overlook is that information itself is useless. Indeed the more information you have, the harder it is to use. A thousand data points are meaningless. ***It is the ability to analyse and interpret information that gives someone power, not raw information!*** This does not just apply in biology, but in any field. We use biology as the tool for teaching analytical skills, but hopefully you will use these analytical skills in other endeavours as well.

A well-conducted experiment or survey collects a great deal of data, but what do you do with all this data? It is not very informative to show someone all your data sheets, catalogues, specimens and field notes; they will be overwhelmed! You need to know how to condense this data and synthesize it to make a report that is scientifically accurate and easy to understand. This is where data analysis comes in. This stage of a project can be just as much fun and challenging as the fieldwork. You will wrestle important conclusions from a huge mass of raw data. When you make conclusions you will have the satisfaction of knowing they are backed-up with real data you collected. More importantly, ***the analysis of data and their communication in a report are <u>essential</u> steps in conducting any research. If you do not analyze and***

communicate your results there was absolutely no point in undertaking the project!!

The basic goal of analysing data is to transform a large amount of numerical and complicated information into a meaningful, easy to understand, shortened form. There are a multitude of ways to do this and tricks to learn. We can only introduce a few of them here (and a few more in the chapter on Advanced Statistics). These are very simple techniques; they do not require fancy computers or a university education. In the course of your training as a scientist you will read many books and scientific articles. Almost all of these present analysed data. Instead of just trying to understand *what* these articles say, start to also look at *how* they analyse and present data. You can learn as much by looking at how someone *does* science, as by what they found out! Methods and results sections in published papers help you figure out how to conduct studies, how to analyse data, and how to present your findings—study them. You need skills as well as knowledge to be a good scientist. In fact, ***proper scientific skills are more important to becoming a good scientist than just having a bulk of factual knowledge.***

There are several basic analytical tools that we will introduce in this chapter: summary statistics, graphs and tables. All of these simplify complicated numerical data. Maps simplify complicated spatial information. A map of your survey study area(s) will be a valuable aid for interpretation of your data. First we will introduce these analytical tools, later we will discuss specifically how to analyse typical quantitative experimental and survey data.

Summary statistics

Mean

The mean is the average. It is one way of saying what the middle of a distribution of numbers is (the median and the mode are other ways). You are probably familiar with averages already. For example when you want to compare your test score with that of your classmates you calculate the average score and see how far above or below the average your score is. So, the average for the class describes the middle of the distribution of test scores for the entire class. To calculate the mean simply add all the values in the distribution and divide that by the number of values. The mean is usually symbolized by an x with a bar over it: $\bar{x}$. The mean is one of the most commonly used and useful summary statistics.

Median

The median is simply the value in the middle of a series of numbers arranged in numerical sequence. If you have an odd number of values the median is the value with an equal number of values on each side of it. If you have an even number of values you take the mean of the two central values. A median is often useful when describing a distribution with a few extreme values that can pull the mean away from the middle of the distribution. Think of a village where everyone earns 500-5000 Kina per year from selling vegetables but there is one guy who is an MP and makes 500,000 Kina per year. Adding his income to find the mean could lead you to say the mean income is 20,000 Kina per year. Using a median weights each value the same and prevents an extreme value[10] from causing distortion.

Mode

The mode is the value that is repeated most often in a set of values; the number that appears most often in a collection of numbers. If every number is different there is no mode. You will see when you plot your data on a histogram what the mode

[10] Extreme values that fall well outside the distribution of the vast majority of values are called "outliers." As in this example they are sometimes easy to identify intuitively, but at other times identifying the outliers is not as easy. There are mathematical ways to identify outliers. Sometimes in statistical analyses it is considered legitimate to exclude outliers. Outliers might result from errors or anomalies that are not typical and can distort analyses. But if you do an analysis where you have excluded outliers, you need to mention somewhere in your report that you did not include certain outliers. You cannot simply exclude data that seems to be inconsistent with your expected results without reporting that you did so.

looks like. You can have a histogram with one mode (unimodal) or with two modes (bimodal). You could have more, but in biological data, unimodal and bimodal distributions are most common.

Examples

Say you collected 1, 2, 3, 3, 3, 4, and 5 beetles in each of 7 pitfall traps one night. You have seven standard sampling units (N=7). In this case the mean, median and mode are all = **3**. Now let's say we add a few more traps the next night and get the following numbers of beetles: 1, 2, 3, 3, 3, 4, 5, 6, 7, 8. This time you had ten traps (N=10). The mode is still **3**, because that value is still the most numerous. However the mean is now **4.2** = (1+2+3+3+3+4+5+6+7+8)/10. The median is now **3.5** = (3+4)/2.

Standard deviation

The standard deviation (SD) is a statistic describing how variable the data are (for more detail see Chapter 12). This is a very important statistic to give in conjunction with the mean. The standard deviation tells you how close most of the values are to the mean. This is almost always of interest when reporting biological data. In fact, you should almost always report the standard deviation, or variation within a dataset, whenever reporting a mean. For example, say the mean grade on your class exam was 80 out of 100 points ($\bar{x}$ = 80). If the SD = 0 then it means that everyone in the class had an 80; we might suspect something is wrong, like the students all cheated and copied the same answers, or that the teacher had given 80 really easy questions and 20 really hard questions. Or, say for example $\bar{x}$ = 80 and the standard deviation (SD) was 10. This tells you there was a fair amount of variation around the mean, some students did better than the mean, others worse than the mean[11]. Summary statistics (like the mean and SD) can help you interpret your data more easily than just looking at the raw data (the whole list of exam scores).

Sample Size

The sample size (n) is also a vital statistic. It tells us how large the sample is and that in turn gives us an idea of how representative our other statistics will be. If we measured three adults from Port Moresby (N=3), we might not have much confidence that the sample can tell us the mean height of adults in the city. However, on the other hand, if we measured 3000 adults (N=3000) we might think our mean statistic is more representative.

If there is only one sample, the letter "N" is used to designate the sample size. If samples are taken from each of "a" populations, then the small letter "n" is used to designate the sample size from each population. When there are samples from more than one population, N is used to indicate the total number of subjects sampled and is equal to (a)(n). If the sample sizes from the various populations are different, then n_1 would indicate the sample size from the first population, n_2 from the second, etc. The total number of subjects sampled would be indicated by N.

The way to calculate the standard deviation is described in the chapter on advanced statistics. Sometimes you will see mean and SD reported as $\bar{x}$ ± SD (e.g., 5 ± 1.2). But the typical way to report summary statistics to describe a set of data is ($\bar{x}$ = value, SD= value, N= value). This short format packs a lot of information into three numbers. Get used to writing this kind of result and interpreting it when others report their results. Be suspicious any time someone reports a mean without also reporting the standard deviation and sample size. Knowing just the mean is not sufficient to draw any legitimate

[11] When we know the kind of distribution the data have we can draw conclusions about how many cases fall within each standard deviation. For example in a normal distribution (the most common in biological data sets) 68.2 % of the observations will be within plus or minus one standard deviation of the mean; 95% will be within two standard deviations of the mean and 99.7% will be within three standard deviations. So in this example, we would know that 68% of the class scored between 70 to 90% on the test.

conclusion. This is a frequent or error (or tactic to mislead) used by journalists and politicians.

Graphs

Graphs take numerical data and put them into a picture. The human brain is designed so that it is much easier to interpret pictures than a bunch of numbers. Computers are just the opposite, they deal with numbers well, but not so well with images. We can take a large data set, hundreds of numbers, and put them into a single image, a graph, that represents the data. This makes it simple for the reader to SEE the result. Normally you should show your results with graphs instead of with tables that just list a bunch of numbers.

You will obtain lots of numerical data in your projects or surveys. Graphing such data does two things: First, it is a form of analysis that lets you quickly interpret the data. Second, it is a good way to communicate large datasets to other people in a way that makes it very easy for them to see what is going on.

There are many kinds of graphs. Here we will introduce just a few of the most commonly used. It is easy to learn how to make graphs. The tricky thing is to learn how to use them as an aid to your analysis. You do not want to just graph all the data you collected on a project. You need to learn how to interpret those graphs.

Scatterplots

Scatterplots are the standard graph relating one variable to another. They are used to show relationships (or correlations), or the lack of relationships, between two variables. Scatterplots require two continuous or sequential variables (like time or numbers—things that can be put in order). You cannot use a scatterplot with classes (which are non-sequential variables like colors or taxa).

Often a correlation is meant to imply a causal relationship (meaning that one variable ***causes*** a change in the other variable), like "the number of birds captured was correlated with the number of nets used." We would suspect that this is a causal relationship. The more nets you use the more birds you catch. BUT, do not make the mistake many people make of confusing a correlation with cause!! ***Just because one thing is correlated to another does not mean that one causes the other!!!*** On the last survey I was on I could have plotted the number of birds I observed against the length of my hair. As the weeks went by my hair grew longer and I also recorded more birds. This does not mean the increase in bird numbers was due to my having longer hair! Both these variables are correlated with time-- the longer I was in the field, the longer my hair grew and the more birds I saw. This example seems silly, but you will be surprised how often people make this mistake, even good scientists!! Think very carefully before you conclude that one thing does or does not cause another thing to happen. In a study you might be trying to determine if a certain logging practice does or does not affect mammal populations. A mistake in your reasoning could lead to poor logging practices based on your recommendations.

You plot paired data on a scatterplot. You plot one datum (this is the singular for "data") that is associated with another datum, e.g., two measurements from the same individual (like DBH and height of a tree, tail length and mass of a rat), or two measurements from the same day (like rainfall and number of captures each day). You plot things you suspect might be related on a scatterplot; you want one to correspond with the other (e.g., you should not plot tail lengths of rats against bird tail lengths—it would be meaningless).

The scatterplot has a horizontal axis called the x-axis and a vertical axis called the y-axis. You plot the dependent variable on the y-axis and the independent variable on the x-axis. With a little practice you will learn to distinguish the two. The dependent variable is something you suspect "depends" on the independent variable. If it is a causal relationship then you think of the independent variable as causing the dependent variable. For example, if the number of frogs singing on night transects goes up with rainfall, we hear more frogs on rainy nights. Rainfall

would be the independent variable causing frogs to sing more; rainfall per night would go on the x-axis and the number of frogs singing per night would go on the y-axis. We think singing depends on rainfall because frogs are more active in the rain. You could just as easily plot number of frogs singing on the x-axis and rainfall on the y-axis, but it is silly to think that frogs singing causes rain! When a frog sings, he is not causing it to become rainy! But the converse is probably true—rainy weather probably does cause frogs to come out and sing. If you get the y and x axes reversed, your graphs will seem weird to scientists, so ***think about which variable gets plotted on which axis before you begin a scatterplot.***

To make a scatterplot, first examine your data to see the range of each variable, and scale each axis accordingly. Next plot each data point (x, y). Find the position of the x value on the x-axis and imagine a line perpendicular to the x-axis from this point (which will be parallel to the y-axis). Find the y value on the y-axis and imagine a line perpendicular to the y-axis (parallel to the x-axis). Where the two imaginary lines cross, that is where you plot that (x, y) point. Do this for all the data pairs. There are computer programs that do this for you instantly, but it is good for you to practice by hand at first, so you understand what is going on. When you are in the field, or you are beginning exploratory data analysis, you will want to roughly sketch some x-y scatterplots to see what you data are look like; this can be very informative.

Once you have the data plotted, you examine it and interpret the picture. If you connected the dots would they make a fairly straight line? A curved line? Does the y value increase with an increase in the x value (a positive correlation) or does the y value decrease with an increase in the x value (a negative correlation)? Here is where your knowledge of biology becomes important-- what does the picture tell you? If there appears to be a relationship between your two plotted variables, why would this be the case? Does rainfall affect singing? Why would we expect the number of species of birds netted to increase with the number of individuals of birds netted? Why might captures of bats be related to the brightness of the moon? It will not be enough just to make graphs; you will need to know which graphs to make and how to interpret them.

See the sections below for species area curves and presentations for scatterplot examples.

Histograms

Histograms are a kind of bar graph. They are similar to scatterplots in that you have an x- and a y- axis that correspond to two variables. However, the x-axis does not have to be a continuous or sequential variable. We often plot classes of data on the x-axis. Even if the x-axis data is a continuous variable, we can still divide it up into classes if we want to make a histogram. For example, if you wanted to plot mass of rats captured on the x-axis you would break this continuous variable (e.g., rats weighing between 10-1000 grams) into discrete classes (e.g., rats that weight 0-50 grams, 51-100 grams, 101-150 grams, etc.). It takes a little practice to learn how to divide continuous data into categories. Basically you divide it so you have enough classes to reveal any patterns in the data, but not too many empty classes (those with no values, or 0). For example if we divided rats into 0-10 g, 11-20 g, 21-30 g, etc. we might find lots of categories between 0 and 1000 with no rats, unless we had an extremely large sample size (n) (and we would have a very long graph with 100 classes on the x-axis!!).

In a histogram we typically plot some expression of frequency on the y-axis. For example, percent of captures, proportion of captures, or actual number of captures. Usually in a histogram we want to portray how a group of data breaks down into certain categories. For example we might want to show how many of the rats captured were of different sizes-- the graph might show us that we caught lots of small rats and lots of very large rats, but not so many mid-sized rats. Or let's take an example with non-numerical data: say we are studying a butterfly with four color morphs. We could plot the

percentage of all captures for each morph; demonstrating which morph is most common and which is rarest. Histograms are useful for showing how often something happened in our data set: how often we found trees of different sizes, how often we caught birds from different families, how often we found frogs in different micro-habitats, etc.

To make a histogram, simply score your data (count the number of values) for each category of interest. Place the categories along the x-axis and plot the counts along the y-axis. If you want percent of the data, simply divide the score for each category by the total number of observations (n) and multiply by 100. For example you captured 250 rats and 43 were in the 50-100 g category. This means (43/250)*100 = 17% were in that category. Or, you can use proportion of observations which is the same thing as percent only you do not multiply by 100. Here is a sample histogram:

How do we interpret Figure 11.1? It looks

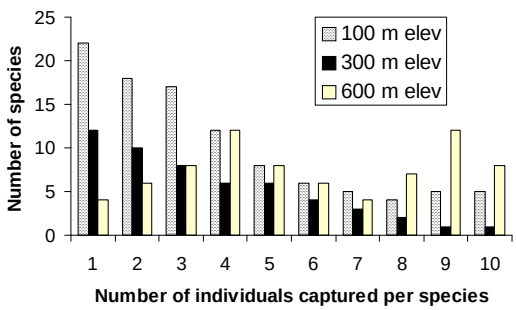


Figure 11.1. Number of species with different numbers of individual birds caught at three survey locations. Birds were mist-netted using the same protocol at each site (see methods). Recaptures were not included in the counts. Total n = 102 species at the 100 m site, 53 at the 300 m site and 75 at the 600 m site.

like the 100 m site has many more species with very few individuals (rare species) than the 600 m site. Can you see this?

Anytime you use a histogram it is necessary to report your sample size (n). You can put this right on the histogram, or you can report it in the figure caption. Sample size is crucial. For example, if you make a histogram that shows 67% of rats captured had ticks and only 33% did not, you might think the population has plenty of parasites. However if your N=3, you would suspect that not enough rats were captured to draw a conclusion about the entire population. ***Anytime someone reports a frequency or percentage without reporting the sample size you should immediately be suspicious.*** Politicians are really good at this; they'll say "67% of the people surveyed in our province want the logging concession," but they might not tell you that they only surveyed 6 people, four of whom were their brothers who work for a logging company! You should apply your scientific skills for critical analysis whenever data are presented in your day-to-day life. You will be amazed (or depressed) by how often people misuse data to support their personal agendas!

Species accumulation curves

Sometimes we want to know if we have found most of the species at a site, in which case we might consider ending our efforts to find more. Or, have we only found a few of the species, in which case we might want to continue or intensify our efforts? Species accumulation curves, sometimes called species area curves, or species effort curves are a graphical way of assessing our efforts to document species diversity. Species accumulation curves enable us to judge whether we have sampled the diversity of a particular taxon thoroughly or inadequately using a particular method.

A species accumulation curve is a scatterplot with sampling effort, measured by your standardized sampling units, on the x-axis. You might have 20 X 20 m subplots on the x-axis for plant surveys, mist-net hours or point counts for birds, trap nights for small mammals, timed transects for frogs, etc.

On the y-axis you plot the cumulative number of species captured or encountered. For example, the first night you set 80 traps and you catch 3 species; you put a point where 80 on the x-axis and 3 on the y-axis intercept. The next night you set 80 traps, for a total of 160 trap nights on the x-axis, and you get one additional

species, so you plot 4 species on the y-axis for the 160 trap nights. The next night you set another 80 traps and get 2 additional species you had not caught before. You plot 240 trap nights on the x-axis and 6 species on the y-axis. The next night you set 80 more traps but get no new species. You plot 320 trap nights and 6 species. A cumulative species curve climbs to the last point, it cannot go down. If no new species are captured, the data point stays level with the preceding data point.

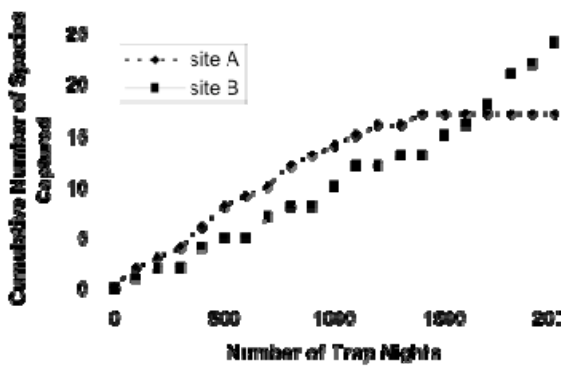


Figure 11.2. The cumulative number of species captured with increasing trap nights at site A and at site B.

Figure 11.2 shows two species accumulation curves, each from a different site. For site A you can see that the curve has essentially leveled-off, or reached its asymptote. This suggests that the biologist has found most of the species at site A that s/he will be able to using that sampling technique at that time. The graph for site A suggests that the biologist will not discover many more species even if s/he samples a good deal more. At site B however, the curve has not leveled-off; it is still climbing. The biologist has not thoroughly sampled the diversity at site B. The graph suggests that the biologist would be well-advised to continue sampling using this technique if s/he wants to thoroughly sample the diversity at this site. Species accumulation curves are an important component of any study documenting biodiversity.

Presentation

When you are exploring your data you can make rough sketches to see what your data look like. However, when you go to include a graph in your report you need to be more careful and follow certain standards.

The x and y axes should be clearly labeled; be sure to include the units for any measurements. The caption below the figure clearly explains the figure. A figure with its caption should be able to stand alone and fully explain what you are seeing; you should not have to read through the report to understand what the figure represents. A person should be able to look at the figure and caption on their own and understand them. If there is not a clear, explanatory caption with the figure, it cannot be used by other people easily. Each figure has a Figure number or letter. This enables you to refer the reader to the figure when you are discussing the results in your report. For example, you can write: *"Frog captures increased when there was more rain in the 12 hours preceding each frog census (Figure 11.3)."*

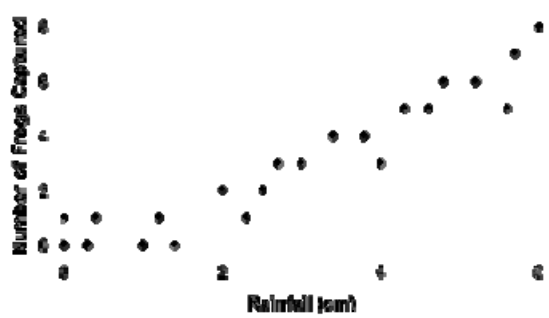


Figure 11.3. Relationship between rainfall and frogs captured on 1-hour timed transect censuses over 22 nights at the Ivimka Camp, Lakekamu Basin, Gulf Province, PNG. Rainfall represents the amount of rain that fell in the 12 hours preceding each timed transect census.

If you plot several things on one graph you must clearly label what the different symbols represent. For example on the previous graph you might also want to plot the number of snakes captured in relation to rainfall. Then you would need two symbols, one for frogs and one for

snakes (Figure 11.4). You show the symbols and what they represent in a figure legend shown within the figure itself.

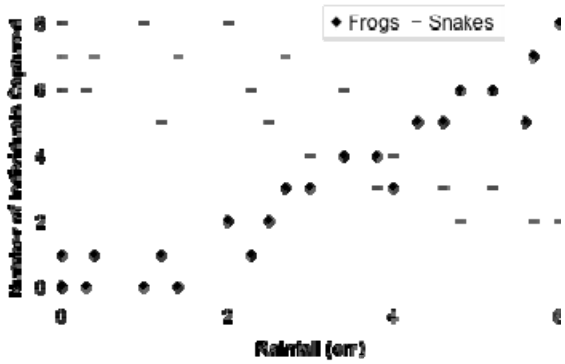


Figure 11.4. Relationship between rainfall and frog and snake captures on 1-hour timed transect censuses over 22 nights at the Ivimka Camp, Lakekamu Basin, Gulf Province, PNG. Rainfall is the amount that fell in the 12 hours preceding each census.

Note that on a scatterplot it is usually easier to see the data if you leave the plot clear of gridlines. There are many "artistic" or aesthetic decisions you need to make about how your graphs will look best and be clearest to interpret. A good rule of thumb is to minimize the amount of ink used, or i.e., maximize the ratio of information to ink used. Symbols should be clearly visible, but not huge. Axes should be clear, but without numbers crowded along them. If your report is going to be published, editors like to eliminate graphs or tables that are extraneous and not really needed because they are more difficult and expensive to publish than plain text. Make sure you graph is adding to you results presentation and is not just there because you figured you needed a graph. However, also remember that as they say, a picture can be worth a thousand words to explain something.

A little practice will teach you when to use a scatterplot and when to use a histogram or some other type of graph. There are few rules for what to use when. Whether to use a proportion or the number of observations on the y-axis is a decision you make. Usually it is best for you to ***plot the data in several different ways and then decide which portrays the most information the most clearly.*** If you examine the graphs in scientific papers closely it will help you to learn the best way to make your own graphs.

Tables

Tables present numerical summaries of your data. Tables are good to use in place of what might otherwise be long, awkward sentences in your report. For example, a sentence like *"We observed twelve species of Columbidae at site 1 and eight at site 2; we observed four species of Cuculidae at site 1 and eight at site 2; we observed nine species of Meliphagidae at site 1 and fourteen at site 2, etc. etc."* This would be better represented as a Table:

Table 11.1. The number of species of different avian families found at two survey sites in Western Highlands Province.

FAMILY	SITE 1	SITE 2
Columbidae	12	8
Cuculidae	4	8
Meliphagidae	9	14
etc.	etc.	etc.

A table enables readers to quickly find the numerical data they are interested in and allows easy, quick comparisons. Note that a Table should have a number and a caption that explains what is in the table, just like with a figure. Note also the table caption goes above the table, but the figure caption goes below the graph, picture or map. The table number allows you to make an easy reference to the data in your report. For example you could write in your results section that *"Pigeons were more diverse at site 1, but cuckoos and honeyeaters were more diverse at site 2 (Table 11.1)."* The reader can then look at the table to see what the actual differences were if they want to, or they can continue reading your fascinating analysis and not worry about the actual numbers. Long listings of numerical results in the text of your report will make tedious reading. Use tables to keep your reports accurate,

but easy to read. If you wish to present a great deal of data in a table it is often better to make that table an Appendix, which comes at the end of your report instead of in the middle of it as a table. It is difficult for the reader to digest a five page table of many numbers stuck in the middle of your results; it gets in the way of his/her reading. You can just say something like *"A complete table of species captured and their dimensions is given in Appendix 1"* in the text of your report. That way they know where to look if they are interested.

There are many clever ways to portray information through graphs and tables. As you read textbooks and scientific papers look at how experienced professionals utilize them. What do you like or dislike about the graphs and tables you see? As a young scientist it is just as important to learn *how* to do science as it is to learn scientific facts. Pay attention to how others do things when you study other people's reports, because one day you will be doing them too.

CHAPTER 12: Advanced Statistics for Field Biologists

Why use statistics?

We go out in the forest and observe things that are interesting-- why do we need to do statistics? Why shouldn't people just take our word for something?

Statistics provide an unbiased, quantitative way to evaluate an observation or phenomenon. Without some form of statistics, everything is essentially guesswork and faith. You use statistics often, though you probably do not realize it. Your basic knowledge of the world is based upon statistics. For example, you put a pot of water on a gas stove to boil and leave the room. You know, based on statistics from previous sampling that your pot will be boiling in a certain amount of time. You have sampled before (you have boiled other pots of water) and can predict how long it will take this pot to boil. If you had never done the subconscious sampling, you would have to stand there and watch every pot of water until it boiled. You have a high degree of certainty that the water will boil in a certain amount of time. That is your probability factor. But as in all statistics, it is a probability. You cannot be 100% certain the pot will boil-- for example the stove could run out of fuel before the water boils.

This seems like an oversimplification, but if you think about it, you have spent your lifetime sampling the world around you. How likely is it that it will rain when the clouds look like this (what is the probability of rain)? How likely is it that the neighbour's dog will bite me? What is the probability that the instructor will be cross if I oversleep and miss the class (this has a high probability!)? You make hundreds of decisions each day based on sampling and statistics. The mathematical field of statistics only formalizes what you have already done all your life. If you had not been sampling and making statistical decisions you would have died long ago (e.g. what is the likelihood I can cross the street without getting hit?).

Rather than thinking of statistics as a specialized, theoretical practice, try thinking of statistics as a tool that you already use. By learning more of the actual mathematics behind statistics, your ability to use that tool will increase. And a good understanding of statistics will improve your life!

Here we learn to apply statistics to the study of biology. Just as you might observe a pot boiling several times and thus be able to predict the water's "behaviour," in biology you might watch an animal and predict its behaviour. If you observe a cassowary eating a fruit, how likely is it that other cassowaries will eat that species of fruit? How likely is it that the same cassowary will eat another fruit of the same species? We don't know until we do some sampling-- observing many cassowaries and what they eat to answer the first question; or observing the same cassowary eat for several days to answer the second question. When we have a set of properly collected observations, we can do statistics to determine an actual probability-- a statistic describing the cassowary's diet.

One of the most important things, as biologists and as observing humans, that we ask of statistics is to separate chance occurrences from actual phenomena. For example, you might be scratching your ear one day when a drunk PMV driver runs off the road, through your house and

into the room where you are scratching, barely missing you. From that single observation, you might conclude that you must not scratch your ear, or something terrible might happen. Was that a chance occurrence, or is there a real link with scratching your ear? One day you could test the hypothesis-- you scratch your ear again. Nothing happens. Another day you scratch, nothing. After a reasonable sample, you can decide it is fairly safe to scratch your ear. (But there is always a chance that something bad could happen again; we are rarely 100 percent certain of natural phenomenon).

Again, this might seem like a trivial example. But what if it happened differently? The second day you scratch, lightning hits your house. The third time your house catches on fire. The fourth time another PMV comes through the wall.... Even if I was not at all superstitious, once I had a reasonable sample of dangerous events every time I scratched my ear, I would stop scratching!

Silly examples? Let's go a little further and venture into the edge of a topic where many people have strong beliefs and where statistics might prove useful. Some people believe in miracles. Let's say a guy buys a Lotto ticket and prays to win, prays for a miracle. That week he wins. Is it a miracle? What is the sample? To him it is a miracle. But if he considers that tens of thousands of other people week after week buy lotto tickets and pray and do NOT win, then maybe it looks less like a miracle and just the one in a million thing that the Lotto really is. Many of the so-called miracles people believe in are just extremely rare events where the 'believers' have failed to do the proper statistics and consider the sample size. Is a potato that looks like Christ on the Cross a miracle? Consider how many millions of potatoes are grown every year, and how many unusual shapes they come in, and then you realize that sure, every now and then JUST BY CHANCE, a potato will look like Christ on the Cross.

But that is a silly example too. Let's look at another example that is perhaps not so silly, but where proper use of statistics could really affect you. A politician is elected to be Prime Minister and just after he is elected, the global prices of coffee, gold, and copra all go way up due to events in other countries. All of a sudden the economy of PNG is doing great. Our friendly politician will undoubtedly claim the good economy is due to him!! He advances a policy of borrowing heavily from international lenders because his policies are so good that the country will surely continue to prosper and be able to pay the debt off. Then the international commodities markets go down again to normal, low levels. PNG is back where it was, but now with massive debt it cannot repay. A poor understanding of statistics (in this case correlation) by the politician resulted in a crisis situation for PNG that takes years to correct. Events like this are all too common and can be avoided with proper use of statistics.

So one important message before we go on to statistics in biology. You can use statistics no matter what you are doing. These skills are not just for biologists. You need them to be a successful biologist, but they will serve you well if you want to succeed in business, politics, or even theology.

Introduction to statistics

The term **statistics** generally refers to numbers that summarize information about a group of objects or a set of observations. You should not be intimidated by statistics. We use statistics to take a complicated data set and simplify it into a few, manageable numbers that tell us something useful about the whole set of numbers. Often this useful information is not immediately apparent when we look at the set of raw data-- this is what sometimes makes statistics seem tricky. Like we said before, you use statistics all the time. For example, you might know that your chances of getting a good job are better if you get a university education. This is a statistic-- the number of people getting good jobs is greater among those with university degrees than among those without university degrees. Or, you might

know that your chances of being in an accident are greater if you drive through a red light than if you stop for the red. Think about the hidden ways that you use statistics every day to improve your life. If you learn more about the proper use of statistics, you will be able to improve many aspects of your life, not just your science.

Usually in biology we are concerned with the relationship between two sets of objects or observations: the set of *all* objects or observations possible, and the *subset* of objects or observations we have actually sampled. In statistics the set of all possible observations or objects is termed the **population**. NOTE: this is a different use of the word "population" than we use in ecology when we denote a potentially inter-breeding group of organisms. The subset of the population that we are actually working with is called the **sample**. We have already discussed samples a great deal in this manual-- a sample is a subset of the entire population that we measure to give us an approximation of the entire population. If we sample properly we can get a good picture of the entire population through the use of statistics. It is important to understand what population you want to sample when you design your sampling, and it is important to understand what population your sample represents when you use statistics to define it.

For example, say we wanted to obtain some statistics (or **parameters)** on the size of crocodiles in the Sepik River. If we clearly define our area of interest as only those crocodiles in the Sepik (excluding all other crocs, like those in the Ramu), then all crocodiles in the Sepik are the population in which we are interested[12]. If we could catch and measure all the crocodiles in the Sepik, we would then be able to measure the **population parameters**. The two basic population parameters of most value and interest are the "average" and the amount of variability. With these two parameters we know a lot about the population.

We would calculate the mean length of the crocodiles and call it the **population mean**, denoted by the Greek letter μ . Where μ = the sum of all the lengths in the population/the number of crocodiles.

We can also calculate the parameter that expresses the amount of variability or **population variance** which is denoted by σ^2

$$\sigma^2 = \frac{\sum_{i=1}^{n}(x_i - \mu)^2}{N-1} = \frac{\sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{N}}{N-1}$$

where x_i is the length of the ith crocodile and N is the population size. The Greek letter sigma (Σ) means "the sum of" so this means you've taken the sum of all the measurements of the crocodiles starting with the first (i=1) on up to the last (the nth) measurement. Note that this is easy to calculate on a hand calculator and most computer programs do it simply. What variance means is not intuitively obvious, especially looking at this formula (!), but in a little while you will see that it is very useful. Variability in a population is more easily understood if you think of it as the average deviation from the mean, which we call the **population standard deviation**, which is normally denoted by the symbol σ. Standard deviation is simply the square root of the variance σ^2

$$\sigma = \sqrt{\sigma^2}$$

An example will help make this clearer. The two samples in the graph below show populations with the same mean (both populations have crocodiles on average about 4 meters long [better not go swimming there!]), but they have different variances (and different standard deviations) (Figure 12.1).

[12] In this example we might think of all crocodiles as the sampling universe. Often it is hard to make conclusions about the universe unless we study many populations, each through many samples.

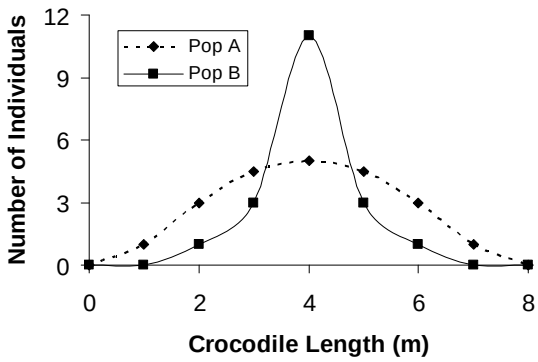


Figure 12.1. The number of Sepik crocodiles of various lengths in populations A and B.

You can see that both populations have crocodiles with an average length of 4 meters, but Population A has more individuals in the 1-3 and 5-7 meter size range than Population B, which has fewer individuals on each side of the mean. This means that Pop A has greater variance (and a larger standard deviation); i.e., it has more individuals farther from the mean.

Unfortunately, we can rarely measure *all* of the individuals in a population of interest. We cannot capture all of the crocodiles in the Sepik and measure them (nor would we want to try this!). Instead we try to obtain a representative **sample** that will give us an idea of what the true population would be if we could measure all of the individuals. We do this not only when we are measuring objects, like crocodiles, but also when we are running an experiment. The results of an experiment are only a sample of all of the possible results if we continued the experiment indefinitely. Thus, it is almost always impossible to obtain population parameters; instead we estimate population parameters by using **sample statistics**. For example, if we know that there are about 6000 crocodiles in the Sepik and we know we cannot catch them all, we might settle for a sample of 60. After capturing and measuring 60 random crocodiles we can then calculate the **sample mean** (or average) denoted by an x with a bar over it ($\bar{x}$) just as you normally calculate an average.

The **sample variance s²** is calculated as:

$$\mathbf{s^2} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1} = \frac{\sum_{i=1}^{n}(x_i^2) - \frac{(\sum_{i=1}^{n} x_i)^2}{n}}{n-1}$$

where n is now the sample size-- in this example 60.

The **sample standard deviation s** is:

$$s = \sqrt{s^2}$$

Note that the sample statistics (denoted by Roman letters instead of Greek letters like population statistics) are only estimates of the population statistics—what we actually want to know. However, it is not possible to know the population statistics so we estimate them using a sample-- note that our sample statistics improve as we use a larger and larger sample size (our estimates for the entire population parameters get better the more of the entire population we sample).

If we were to take several successive 60 crocodile samples from the Sepik (returning the crocodiles after each sample), say 20 samples of 60, we would find that our sample means would not always come out exactly the same. But, our sample means should vary less than individual variations (the difference between any two crocodiles). It turns out that the standard deviation of the sample means (treating each mean as a single measure-- so we have 20 measures in the above case) is equal to the standard deviation of the sample observations divided by the square root of the total sample size (that is the square root of 20*60 crocodiles). More precisely, the standard deviation of the sample means, called the **standard error**, or **SE**, is:

$$\mathbf{SE} = \sqrt{\frac{s^2}{n}} = \frac{s}{\sqrt{n}}$$

Obviously one can calculate the standard error from a single sample, but you would not bother doing this-- its intuitive definition deals with several samples with different means. The standard error gives us an idea of how variable means from different samples are, just like the standard deviation gives us an idea of the variation around the mean within a single sample.

Another measure of variation you might sometimes use is called the **coefficient of variation CV**. This is useful in comparing the variation in two samples that have very different means, for example the length of tails on rats and wallabies. You probably won't have much need to use this, but it is good to know.

CV = $100\left(\frac{s}{\bar{x}}\right)$ or simply, the standard deviation divided by the mean, then multiplied by 100.

Alright! If you understand means and standard deviations you already have the foundation for working with statistics. In previous chapters we talked about designing uniform sampling techniques. If you sampled all the frogs on ten 5 X 5 quadrats at each of two locations, say at Varirata and Lakekamu, you have the basics for some statistical analyses. You can calculate the mean number of frogs per quadrat at each site (Varirata and Lakekamu) and the standard deviation in the number of frogs at each site. You can use these statistics to describe the frog communities at each site. But you can also use them to compare the two sites. The point of field surveys is to first describe the biota at a site, and then to compare that site to other sites: ***Sample, describe, compare-- then make conclusions.*** We use statistics to make our comparisons.

The normal distribution

If we measured crocodile body lengths or any other variable enough times, we would probably find that our frequency histogram would approach a bell-shaped curve, the famous normal distribution as shown in Figure 12.2.

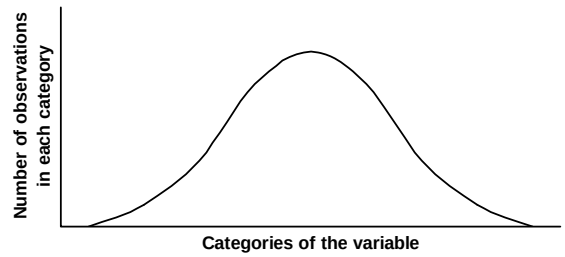


Figure 12.2. A typical normal distribution.

Observations on a normal curve will cluster around the highest point on the curve (remember that this point is called the mode; if the curve is symmetrical, the mode and the mean are the same number). Amazingly enough, even if individual measurements do not approach the normal curve, if we take a number of samples then plot the means or variances of those samples, they DO approach the normal curve!

For example if male and female crocodiles are very different sizes, we might get a curve that is bimodal, meaning there are two peaks, one reflecting the male, and one the female, average (Figure 12.3).

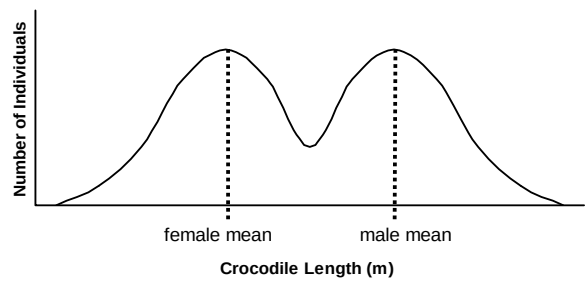


Figure 12.3. Crocodile length distribution showing female and male bimodal means.

But, if we take a number of samples from this population and plot the means of each sample, we would get a normal bell curve with only one peak, as in Figure 12.2.

The normal curve is the basis for the field of parametric statistics. In many statistical operations we assume that the population we are sampling approaches the normal curve (even if individual samples do not, as discussed above), and that the curve is more or less symmetrical and not strongly **skewed** (meaning distorted to the

right or left, like having one tail stretched out). The following hypothetical distribution of the heights of people from Papua New Guinea shows a skewed distribution (Figure 12.4).

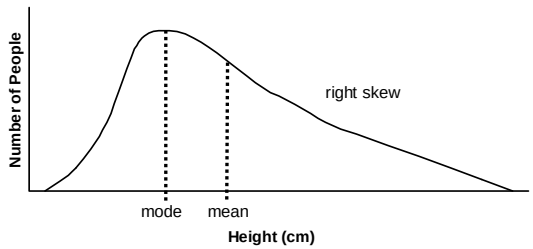


Figure 12.4. Skewed distribution of a sample of human heights in PNG.

Why might a distribution of the height of people from PNG show a skew like this? Well, in PNG there are many more young people than adults (an indicator of a growing population), so if you sampled all ages randomly, you would get more children than adults and the number of people in the shorter size classes (left side of the x-axis) would be more than those in the taller classes (right side). The skew would disappear and the distribution would be normal if, for example, you only measured adults above the age of 20 and plotted those results.

Let's go back to our unskewed normal distribution. If we have a normal curve for a population, we can then point out which observations are one standard deviation, two standard deviations, and so forth away from the mean (and mode since they will be equal in a normal distribution) (Figure 12.5).

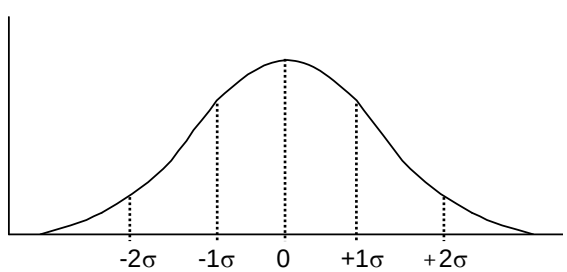


Figure 12.5. A standard normal curve with mean/mode equal to zero showing 1 and 2 standard deviations.

So we can define any single observation not only by its particular value (say a crocodile 3 meters long), but also by its distance from the population mean in terms of σs. This is called the **z-value** (sometimes called the τ - value just to confuse us!), or we can call it the **standardized normal deviate** where:

$$Z = \frac{x - \mu}{\sigma}$$

Or, we can say that z is normally distributed with population mean = μ = 0 and population standard deviation = σ = 1. For instance, z = 3 means that x is 3 standard deviations from the mean. The important thing for you to get from this is that on the standardized normal curve we know what percentage of our observations fall within an area under the curve bounded by different z values. We know that 95% of the observations fall within ± 1.96 σ, and that 99% fall within ± 2.57 σ. This knowledge is what will enable us later in this chapter to test the likelihood of our observations being from a certain distribution or not (if that distribution is normal).

Since two sample sets of observations are unlikely to be exactly the same, we need to know if the two sets do come from the same underlying distribution or population and just happen to differ by chance, or if they come from different distributions or populations. Or in other words, do differences in our observations really indicate that there are two different underlying distributions or not. We can assess this statistically. For instance, we can tell if the trees at one site really are larger than at another site, or if it just seems this way because we happened to include a few larger trees by chance in one sample. Many of you might be familiar with the use of statistics in sports-- just because one rugby team wins a match does not mean that it is really better. If you look at the statistics for the teams you might see that the losing team actually performs much better most of the time and that it

lost this match more by chance than because it is a poorer team.

Confidence intervals

If we could measure an entire population, we would know the population parameters and would need to go no further. If we needed to know μ and σ, we would simply calculate them (because we have all the possible values of the variable). If we were comparing two populations, say the crocodiles from the Sepik and the Ramu Rivers, and wanted to know if the two populations differed in mean length or variability we would know this easily. Any difference we observed would be real because we measured the *entire* population at both sites. But, we hardly ever have *entire* population data sets, usually we only have smaller subsets, or samples of the populations we are interested in (for example 60 crocodiles from the Sepik and 60 from the Ramu). Do the differences we see in these samples indicate real differences in the underlying distributions (the population parameters)? Or, do the differences in these samples just indicate differences due to chance sampling artefacts and the underlying distributions are actually the same? These are fundamental questions we ask and answer with statistics.

We do not really know just how good $\bar{x}$ and s are as estimates of μ and σ, especially if our sample size is small (what could we say if we measured only one crocodile from the Ramu and one from the Sepik?, if we measured two, three, ...1000?). Are the differences we observe real differences between the populations? With our growing knowledge of statistics we cannot say *for certain* whether a difference is real or a sampling accident, BUT we can determine the probability that these differences are true of the underlying populations or not. We can determine how likely it is that a difference is real or just due to chance.

For example, say we take our 60 crocodile sample from an underlying population of 600 crocodiles, and that we want to know what the *population mean* is (for the whole 600 crocs), even though we only have a *sample mean* (taken from 60 crocs). We first assume that the distribution of crocodile lengths in the population is a normal distribution and that the distribution of our sample at least approaches a normal distribution. Then we can calculate the range of values within which μ (the population mean) probably lies, given that we can calculate the sample standard deviation from our sample. Remember that 95% of observations on the normal curve lie within $\pm$ 1.96 σ of the population mean (one standard deviation). Therefore, 95% of observations of the sample mean must lie within $\frac{1.96\sigma}{\sqrt{n}}$. Or, we can say that the interval $\bar{x} \pm \frac{1.96\sigma}{\sqrt{n}}$ will cover μ 95% of the time, and will not cover it 5% of the time. Or to rephrase again, the probability that $\bar{x} - \frac{1.96\sigma}{\sqrt{n}} < \mu < \bar{x} + \frac{1.96\sigma}{\sqrt{n}}$ is 95%. Of course, we could not be absolutely certain that this interval covered μ, but usually if we can be 95% certain of something we consider it a safe assumption.

BUT, the above formula is not very useful! We do not know σ! And the smaller our sample size, the more two things happen to mess us up: our sample distribution gets farther away from a normal distribution, and s gets farther away from σ. The solution: a handy statistic called the ***t*-statistic**. The *t*-statistic is about as accurate as z is for large sample sizes, but it is better than z when you only have a small sample size. The real beauty of the *t*-statistic is that it is given for you for various sample sizes and various probabilities (e.g. 0.95, 0.99) in almost every statistics book or set of statistics tables. A copy is shown in Appendix 3 of this manual.

The *t*-statistics are listed for various **degrees of freedom, ν or d.f.** The ν symbol is used in equations and d.f. is usually used in tables and text. Degrees of freedom is simply the sample size minus one (n-1). To use the Table we also need to understand **alpha** α. This is the probability that our result shows a real difference—the opposite that our result does not show a difference and actually does lie within the

confidence interval. If we want to be 95% sure that our sample mean is within the confidence interval we need to look up $\alpha = 0.05$. (If we are 95% sure we are within the confidence interval then that leaves a 5% chance we are not—that is how we get $\alpha = 0.05$) You will learn more about α later in this chapter, but for now simply think of α as the probability that the mean is outside of the confidence interval.

So, given a sample of size n and degrees of freedom (n-1), we look up the *t*-value for $\alpha = 0.05$ (95% sure) or $\alpha = 0.01$ (99% sure) (or whatever probability we want to put on our estimate of the population mean) in the Table. With this and the following formula we can determine the confidence intervals for the population mean, that is, the numbers between which μ lies with 95% probability, or 99% probability, or whatever probability:

$$\bar{x} - (t \text{ for } \nu, 0.05)\left(\frac{s}{\sqrt{n}}\right) < \mu < \bar{x} + (t \text{ for } \nu, 0.05)\left(\frac{s}{\sqrt{n}}\right)$$

this is the *t* value you look up in the Table to be 95% sure.

Or:

$$\bar{x} - (t \text{ for } \nu, 0.05)\,(\text{SE}) < \mu < \bar{x} + (t \text{ for } \nu, 0.05)\,(\text{SE})$$

Let's go through an example with a small sample size-- one that could be reasonably done on a real field project. Let's say we sampled crocodiles from Chambri Lake; we caught 10 crocodiles (so, N = 10) and measured each one to get a mean length of 60.43 cm (so $\bar{x}$ = 60.43 cm). We calculated the variance of our sample and got 9.35 cm (so s^2= 9.35); we know that the standard deviation is simply the square root of variance (so s=3.06 cm). We can calculate the standard error of our sample because SE is the standard deviation divided by the square root of the sample size ($\frac{s}{\sqrt{n}}$) or, in this case SE= 0.968. To use the table we'll also need to know the degrees of freedom (df = n-1, or in this case 9). See how you can get some important statistics just from a little sampling? All we've done is catch 10 crocodiles (not so tough since they were sort of small!) and measure them.

We have the following statistics:
N = 10
df = 9
$\bar{x}$ = 60.43 cm
s^2 = 9.35 cm
s = 3.06
SE = 1.02

We want to be 95% sure that our confidence interval covers the population mean, or in other words, 95% sure that the real population mean is within the interval we will calculate around our sample mean. So, we use the t-statistics table (in Appendix 3) and look up the values under df = 9 and $\alpha = 0.05$. We see that $t = 2.262$. So we can now estimate the confidence interval using the formula:

$$60.43-(2.262)(0.968)<\mu < 60.43+(2.262)(0.968)$$
$$= 58.24 < \mu < 62.62$$

Now we finally have our result! We can say that there is a 95% probability that the mean length of all crocodiles in Chambri Lake lies between 58.24 cm and 62.62 cm. Symbolically we write this as $P(58.24 < \mu < 62.62) = 0.95$.

So instead of just having a measure of the mean taken from just ten crocodiles, you can now say with a statistical certainty where the population mean actually falls!

Probabilities and hypotheses

Probabilities

Before proceeding with a different use of the *t*-statistic, we must discuss the process of statistical testing in general. Given a sample drawn from a larger unknown population, we can never say with *absolute* certainty that we know where the population mean and variance lie; we cannot say with *absolute* certainty that two samples come from different populations; we cannot say with

absolute certainty that some event will *never* happen.

For example, if we flip a 20 toea coin 100 times and every time it comes up a muruk, we cannot say absolutely that there is something biased about this coin (or the guy flipping it). This is true even though we all know that flipping a 20 toea coin should come up about half the time with the muruk and half the time the emblem of PNG. But it *is possible* to flip a coin 100 times and have the muruk come up every time. With a knowledge of statistics we can say exactly what the **probability P** is that you will get 100 muruks in a row (other than just very low!). Probability is expressed as a proportion, with 1 = absolute certainty that something will happen, and 0 = absolute certainty that something will not happen. If all possible outcomes are equally likely to occur (in this case either the muruk or the emblem could equally come up), then P = the number of outcomes with X occurring/the total number of possible outcomes. So in this case the probability of getting a muruk from a coin toss is 1/2 (one of two possible outcomes assuming the coin cannot land on its side) = 0.50. The probability of getting one muruk, then another in succession, then yet another in succession = $(0.5)^3$ = 0.5 * 0.5 * 0.5 = 0.125. So you can see that getting 100 muruks in a row would occur with a probability of $(0.5)^{100}$ which is an incredibly small number! You multiply individual probabilities to see the likelihood of them *all* occurring (like in this case where you get many muruks in a row), and you add probabilities to see the likelihood of *either or any one* of them occurring (say we wanted to see whether either a muruk *or* an emblem would come up, the probability would be 0.5 + 0.5 = 1.0 (assuming the coin cannot land on its side).

So, as scientists, we might not be able to know things with *absolute* certainty, but we can say how certain we are by calculating probabilities. If we are 99% certain of something (0.99 probability), that is usually good enough. I would buy a lottery ticket with a 0.99 chance of winning; I would not buy one with a $(0.5)^{100}$ chance of winning.

Hypotheses

When you set-up an experiment or a data collection procedure, you should set forth two hypotheses. The **null hypothesis** (symbolized as $\mathbf{H_o}$) will always be that there is not a difference between two samples, or that there is no relationship between two things. The null hypothesis is the statement of a negative or lack of something. Some examples of null hypotheses might be: there is no difference in the height of people from Gulf and Morobe Provinces; there is no difference in the forearm length of fruit bats from the roost in Madang and the roost in Lae; there is no difference in the density of clown fish in Milne Bay and Rabaul Harbor; there is no difference in the density of birds in Lakekamu forest and Varirata forest. Just about any time you want to study something in biology you should start out with a clearly-stated null hypothesis. Practice making null hypotheses as you do your field work associated with this course.

The second kind of hypothesis is called the **alternate hypothesis** (symbolized with $\mathbf{H_A}$), which states that there *is* a difference, a change, a relationship, etc. between two things. For example we could make alternate hypotheses that people from Morobe Province are taller that people from Gulf; that fruit bats from Madang are smaller than those from Lae; that the density of clown fish in Milne Bay is greater than at Rabaul; or that the density of birds at Lakekamu is different from the density at Varirata. Learning how to properly formulate your null and alternate hypotheses is an important first step to any study.

All that a statistical test does is put a numerical probability on the validity of the null hypothesis, given our sample data. Based on this probability we either accept the null hypothesis or we reject the null hypothesis. If we reject the null hypothesis we might consider the alternative hypothesis to be true. But, ***in statistical tests we cannot actually prove that a hypothesis is true.***

There could be many possible alternative hypotheses to consider if we reject the null hypothesis. At first glance we might think that our data support the alternate hypothesis; but that impression could be wrong and could be due to what we call sampling error. We might have by chance chosen a few really tall people from Morobe and our alternate hypothesis might not really be true because of this sampling error (we discussed in earlier chapters the importance of getting representative samples and samples that are randomly chosen). We want to be as sure as we can that when we reject a null hypothesis we are not doing so because of sampling error. So we usually set our probability level at 0.95 (or 95%) which is a pretty high level of certainty. Thus we set $\alpha = 0.05$ (α is the probability that the null hypothesis is correct and that we are wrong to reject it). So if we reject the null hypothesis with $\alpha = 0.05$ we are saying we reject the null hypothesis with 95% certainty that we are correct in doing so, or in other words that there is a 5% chance we are wrong to reject it. Sometimes we want to be even more certain so we set our $\alpha = 0.01$. The 0.05 and 0.01 levels are standards used for most statistical tests and thus most printed statistical tables give appropriate test values for these probabilities.

So, there has been a lot of talk that might not make a lot of sense to you yet. DO NOT WORRY IF YOU ARE CONFUSED! Statistics will only start to make sense with a little practice. Now we will start practicing actual statistical tests you can use in your research, and it will all start to make more sense!

Parametric Statistical Tests

The *t*-test

Let's say we have two samples with sets of statistics we have calculated (like we did for confidence intervals). We have two means $\bar{x}_1$ and $\bar{x}_2$, and two variances s_1^2 and s_2^2, and we want to see if these sample differences indicate a true difference in the underlying population means. Or, in other words, we want to see if our data are good enough to enable us to reject the H_o at $\alpha = 0.05$ that the populations have the same mean. There is a relatively simple formula we can use to do this. Most computers and many hand calculators can do this test for you in a flash, but if you are not lucky enough to have such a machine, or you are out in the bush you might need to do it by hand. It is not hard! Doing *t*-tests by hand is a good learning exercise.

$$t = \frac{\left(\bar{x}_1 - \bar{x}_2\right)\sqrt{\dfrac{n_1 n_2}{n_1 + n_2}}}{\sqrt{\dfrac{\left(n_1 - 1\right)s_1^2 + \left(n_2 - 1\right)s_2^2}{n_1 + n_2 - 2}}}$$

where n_1 is the size of the first sample and n_2 is the size of the second; s_1 is the SD of the first sample, s_2 is the SD of the second sample. Calculate *t* with this formula then go to the *t*-table in Appendix 3. Look for the *t*-value for your pre-determined α and the appropriate degrees of freedom (ν or df). In this case df = $n_1 + n_2 - 2$. If your calculated t-value is equal to or greater than the value given in the table, you can reject the null hypothesis and say that there is a statistically significant difference between your two samples (in other words the two different sample means reflect real differences in the two populations you sampled). If the t-value you calculated is less than that given in the table, you accept the null hypothesis, and you conclude that there is not a significant difference in your two sample means (that the two samples come from the same population and the means aren't really different).

Most statistical tables give 1-tailed and 2-tailed α levels. You will notice that the 1-tailed test is a bit more powerful than the 2-tailed (it's easier to get a significant difference). If your alternate hypothesis does not specify the direction of the difference, it is a 2-tailed test. For example your H_A might be that crocodiles from the Sepik River and the Ramu River are different sizes. But if you say which way you think the difference will be BEFORE you collect the data, it is a 1-tailed

test (you have a good reason for predicting a difference in one direction, 1-tailed, and so you have more power than if you were just guessing that there might be a difference for no reason, 2-tailed). For example, you could use a one-tailed test if your H_A was that crocodiles from the Sepik are larger than those from the Ramu because the Sepik has more food for them. You must decide if you are doing a one-tailed or a two-tailed test *before* you look up the values in the table.

The F-test and Analysis of Variance (ANOVA)

Sometimes we do not want to know if the means of two samples are different, but we do want to know if the variances from two samples are different. For example, if all the crocodiles from the Sepik were exactly three meters, the mean length would be 3 m; now imagine if the crocodiles in the Ramu ranged from one to six meters, the mean could still be 3 m. So, two samples could have identical means, but we might want to check to see if the variances are different.

The main use of the F-test is in the analysis of variance (ANOVA). What if you have several different samples that may or may not come from several underlying populations or sets of observations? What if you planted several plots with coffee, treated each with a different concentration of fertilizer, and wanted to know if the fertilizer had a significant effect on growth? You could analyse several treatments or samples simultaneously using ANOVA. It is complex mathematically, so we won't give you its big formula to use. Most computer statistics programs do it for you. We will not get into this here, but you should be aware that ANOVA exists. Once you learn a little more about ANOVAs you can set-up experiments and test for several things at the same time, like testing different fertilizer brands at different concentrations all in one experiment. This way you can learn about interactions in variables that might not be evident in paired experiments. For example, coffee might grow faster with a certain brand of fertilizer, but only at one concentration, while at a different concentration another brand works better. For now you should just be aware that there are statistical methods to detect such things from a single experiment. Later in your careers you will learn more about ANOVA.

Regression and Correlation

Often you will want to know if a change in one variable is associated with a change in another variable. For example, we might want to learn if longer crocodiles weigh more than shorter crocodiles. So, we go back to the Sepik and this time when we catch and measure the length of the crocodiles, we also weigh them. Now this certainly seems like a simple example, but let's use it anyway-- there's more to learn than just if this is a true-or-false question (e.g., just how much heavier is a 2 m crocodile than a 1 m crocodile?). We might want to learn how to *predict* the weight of the crocodile from its length. If we could do this, for example, we might be able to estimate the length of a swimming crocodile and then predict its weight based on our statistics. This could sure come in handy if we do not want to capture and weigh every crocodile we see, especially the big ones!

You might want to use correlation analysis in experiments. We might grow coffee seedlings at different light intensities and want to know if there is a relationship between light intensity and growth. In this case light is the variable we control, called the **independent variable**, and growth is the measured variable, called the **dependent variable**. We want to see if the dependent variable "depends" on the independent variable (remember that the two are not interchangeable-- light levels do not depend on growth rates, but growth rates can depend on light levels!) Remember from our earlier chapter that when you make a graph, or scatterplot, you always put the independent variable on the x-axis (horizontal axis) and the dependent variable on the y-axis (the vertical axis). If you do this wrong, your graph will seem nonsensical and other scientists will have a hard time understanding it.

In a controlled experiment, like our example of regulated light, it is easy to tell the

dependent and independent variables, but often it is not so easy-- for instance our example with length and weight of crocodiles. That is alright, we can still try to measure the relationship, the dependence, or the correlation between two variables, even if there isn't an obvious dependent variable. We use a process of calculating the algebraic expression that best fits the relationship between X and Y (our two variables); this process is called **regression**. The simplest type of regression is **linear regression**, in which we calculate the straight line that best fits the relationship. Linear lines on a graph are expressed by the formula y = a + b(x). This formula tells you the value of y when you know x; you can predict y if you know x, or x if you know y. This is what we wanted to do with our crocodiles-- predict their weight (y) by estimating their length (x). In this formula a is the term for the y-intercept: the point where the regression line crosses the y-axis. The term b refers to the slope which we can think of as the change in y divided by the change in x, or: b= $\frac{\Delta y}{\Delta x}$ or as it is sometimes called, the rise over the run.

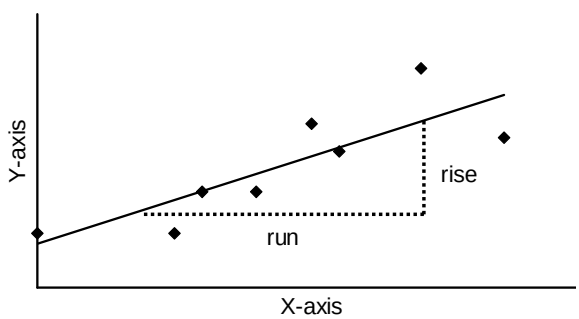


Figure 12.6. Scatterplot with linear regression line.

Figure 12.6 shows a scatterplot with a regression line drawn in to fit the points. Each point represents a related pair of measurements, e.g., the length (x) and weight (y) of a crocodile. Most calculators and computers can calculate the formula for the straight line that best fits the set of x and y points in a data set. If you do not have a calculator you can make a graph and plot all your points, then draw a line that seems to fit the points, and then measure the rise over the run to get "b" and look at where your line crosses the y axis to get "a." But this depends on how well you can draw a line to match the data and it can be time-consuming to make the graph. You can do the calculations by hand, and more accurately determine where the line should go, with the following formulae:

$$b = \frac{\sum xy - \left(\frac{\sum x \sum y}{n}\right)}{\sum\left(x^2\right) - \left(\frac{\left(\sum x\right)^2}{n}\right)}$$

$$a = \frac{\left(\sum y\right)\left(\sum x^2\right) - \left(\sum x\right)\left(\sum\left(xy\right)\right)}{n\sum\left(x^2\right) - \left(\sum x\right)^2}$$

or, if b has been calculated, a = $\bar{y} - b\bar{x}$

There is a fairly simple method for determining the significance of b, that is, of determining if b (the slope) is significantly different from 0 (or another b). A b of zero would indicate that there is no relationship between x and y. We could also test to see if our observed b happened to arise by chance (sampling error). We will not go into this test here, but you should be aware that it can be done. Most computer programs do this automatically whenever you estimate a regression.

Correlation tells us how good the fit is between the points and the regression line. Correlation tells us whether x and y vary in the same direction in opposite directions, and how much scatter there is (how close the points are to the regression line). The correlation coefficient tells us how good the correlation is (how good a predictor the regression line is for the data). The correlation coefficient is usually denoted by r. It can be positive if both the x and y increase together, or negative if one increases as the other decreases. If there is no correlation, the coefficient r = 0; if it is a perfect correlation, the coefficient r = 1; not perfect and not totally non-existent correlations lie between 0 and 1 or 0 and -1.

Consider the three examples below:

(a)		(b)		(c)	
X	Y	X	Y	X	Y
1	2	1	3	1	1
2	4	2	2	2	2
3	6	3	1	3	1

In (a), for every increase in x there is a corresponding increase in y (2 times x). This correlation is perfect, and is positive, so we say r= 1 (perfect positive correlation). In (b), for every increase in x there is a corresponding decrease in y; by knowing x we can perfectly predict y, and we would say the correlation coefficient r = -1 (perfect negative correlation). In (c) however, we cannot predict y by knowing x; there is no relationship, and the correlation r = 0. The correlation coefficient gives us a measure of how good the fit is for the regression, or in other words, how good one variable is as a predictor of the other; it is always somewhere between 1 and -1.

We calculate the correlation coefficient with the following formula:

$$r = \frac{n\sum(xy) - (\sum x)(\sum y)}{\sqrt{\left[n\sum(x^2) - (\sum x)^2\right]\left[n\sum(y^2) - (\sum y)^2\right]}}$$

Now we have the mechanism for predicting the weight of crocodiles if we have the length. The nice thing about correlation is that you can test r for significance. Remember that whether you are measuring crocodiles or conducting a coffee growth experiment you are only drawing a sample of observations from a much larger population (or sampling universe). If you find a good correlation in your sample, there is still a chance that if you were to continue measuring or experimenting that the correlation would decrease, perhaps to 0. Of course, the larger your sample, or the closer your correlation coefficient is to 1 or -1, the less that probability is (of a spurious correlation due to sampling error); BUT, there is still that chance. Therefore, we must determine whether r is statistically significant or not.

It is easy to check the significance of r. Just refer to the Pearson Correlation Table in Appendix 3 and look at what value it gives for your chosen α level and n-2 degrees of freedom where n is the number of sample pairs. If your calculated r is greater than the value of r shown in the table for your α and ν, then you can conclude that the correlation coefficient is statistically significant-- there is a relationship between the two variables in your sample and the line is a good predictor.

It is VERY IMPORTANT to remember that a correlation does not mean X causes Y or Y causes X. For example, as I get older the diameter of my belly increases. Also as I get older the population of PNG increases. We could collect samples over time and get a statistically significant correlation between the size of my waist and the population of PNG. This is a mathematical reality BUT you should not interpret this to mean that my belly is causing the growth of PNG's population, nor is the increase in PNG's population causing me to get fat! This sounds very silly, but you will be surprised how often this misuse of statistics occurs, in science and elsewhere. For example, very often politicians will say that since they have been elected more roads have been built, or more schools have been built, or the crime rate has dropped, etc. These might be true correlations, but it does not mean there is a causal relationship!! You need more information (preferably a controlled experiment) to determine if there is a causal effect tied to an observed correlation. Do not make the mistake of drawing poor conclusions from otherwise good statistics!!

You should be aware that there are also methods to fit curved regression lines to data. There are many correlations that are best fit by lines that are not straight (global population growth is a good example). We will not go into these methods here, just know they exist. If you are using a computer statistics program, these

methods are easy to use, and you can get predictor curves instead of straight lines.

Types of data and types of questions

The tests described above (t-test, anova, Pearson correlation) depend on sample parameters that follow the normal distribution and are called **parametric statistical tests.** These are useful tests and important for you to learn. BUT, they rely on certain assumptions that might not be met in field biology. After all the work you've done to get this far in the statistics chapter, you'll be pleased or annoyed to learn there are other tests that can be better (and sometimes easier) for you to use. Even if you choose not to use parametric tests on a project, the knowledge of how they work is important for understanding statistics in general; that is why we have spent so much effort going over them in the first half of this long chapter.

Parametric tests assume:

- The variables are continuously distributed. (for example the variables are not in classes like small, medium and large, but are in continuous units, like meters).
- Observations are independent and no observation influences the chance of making another observation. This would require (among other things) that we throw every crocodile we measure back into the river and if we re-catch one, we re-measure it. Also that it is just as easy to re-catch a crocodile as it is to catch one the first time.
- The underlying populations follow the normal distribution and are not strongly skewed.
- The different populations being studied (e.g., crocs in Sepik and Ramu) have equal variances.

Often we do not have data that meet all of these assumptions, and we cannot use parametric tests with such data.

We will now consider some of the possible types of data we might collect in field biology as these will affect whether we can use parametric tests on them or not.

Nominal data

Nominal data are data in classes; they are non-numeric and cannot be put in numeric order. We might have two or more data categories that only have names, like birds of paradise with yellow plumes and those with white plumes. We can tally the frequency that each color occurs, but we cannot calculate a mean yellowness, or a variance in plume color. Nor can we rank these data; white is not larger or heavier than yellow.

Ordinal data

These are data sets that are numerical (whole numbers) that can be ranked. Ordinal data usually represent counts, like the number of organisms or objects on a plot.

Interval data

If our data have all the characteristics of ordinal data, but we can also give observations a precise value on a continuous scale, then we consider it interval data. Interval data can have values between whole numbers, like measurements do. When using parametric tests you must be using interval data.

There are also different types of questions one can ask with data and we can categorize these too. It is not so important to remember all these categories by name; but at least start thinking about the different forms of data and the different ways we test ideas. You should try to develop an intuitive understanding of data and how to use it. A good way to do this is to look at how other scientists analyse their data in scientific publications. Do not just look at the end results of a scientific paper, but ***study scientific papers to see how scientists got their results—what methods did they use and how did they analyse their data—this is a vital component of your training***. You must not only study and learn scientific "facts", but you must study *how* to do science-- science is a technique as much as a body

of knowledge. Anyway, enough free advice! Back to categories of statistical questions.

Many data consist of only one sample and are tested with **one-sample tests**. The most common example of this is when you want to test to see if your data fit some predicted frequency. For example, you might predict that the crocodiles in your sample have a 1:1 male to female sex ratio. You sex the crocodiles that you capture, your one sample, and compare it to a predicted number. So if you caught 100 crocodiles you would predict 50 male and 50 female crocodiles. The most common statistical test to use here is the chi-square test, which we describe below. This is a really useful test!

There are also tests for **two related samples.** This is where you sample one set of things, do something to them and then sample the same group again. An example might be measuring growth of coffee plants, fertilizing them, then measuring their growth again. This type of test is less commonly used by field biologists like you, and more commonly used in lab experiments, so we won't go into these tests in this course. Just know they exist.

Many studies require tests for **two unrelated samples**; these are samples taken from two populations that may or may not be different. The point of the test will be to determine if they really are statistically different. For example, your vegetation plot data from Varirata and Lakekamu-- two samples we think are separate populations (in the statistical sense). We will introduce several tests below that are good for two unrelated samples; we have already introduced the *t*-test, which is the parametric test to use. But you must use non-parametric tests if the data do not meet the assumptions of a parametric test. If you are uncertain it might be safer to use a non-parametric test. On some occasions you might have more than two unrelated samples. You could use ANOVA for these (parametric) or there are non-parametric tests you could use, such as the chi-square k-sample test (see below) or the Friedman test.

Finally, you have already learned something about parametric tests for the **relationship between two variables**, i.e. regression and correlation analysis. However, there are also non-parametric tests for this, like the Spearman rank correlation test discussed below. Again, you must use these when the assumptions of parametric tests are not met, which is often the case with field data.

Non-Parametric Tests

The Chi-square test for one sample

This is a good test anytime you have one sample, even if you only have nominal data. For example, suppose we predict that the sex ratio of rats is 1:1. (So, H_o= the sex ratio is 1:1, H_A= the sex ratio differs from 1:1). You should think of this as a two-tailed test, because we have not predicted the direction of the difference-- we have no prediction beforehand that there will be more male or more female rats. Also, beforehand we set $\alpha = 0.05$. We do a lot of trapping and get 350 rats; of these 150 are males and 200 are females. Does this mean there are really more females in the population, or is it a result of sampling error? That is why we have statistics!

If the population was exactly 1:1 and there was no sampling error, then we would predict 175 males and 175 females in a sample of 350. So basically what we do is test our one sample against this predicted frequency. Is our observed observation far enough from the predicted to reject H_o? First we determine the chi-square value (χ^2) using the following simple formula:

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$$

where O is the observed value for a category and E is the expected value for that category.

In this case the calculation goes:

	males	females
O	150	200
E	175	175
O-E	-25	25
$(O-E)^2$	625	625
$(O-E)^2/E$	3.57	3.57

So, $\chi^2 = 3.57 + 3.57 = 7.14$

The degrees of freedom (or df) is simply the number of categories minus one (in this case 2-1=1). Now we go to the chi-square table (Appendix 3) and look at the value in the table for $\alpha = 0.05$ and $\nu = 1$. The value given is 3.84. Our χ^2 value is greater than 3.84, so we can reject the null hypothesis. We can conclude that the underlying population does not have a sex ratio of 1:1. Now we can wonder why there are more female rats than male rats, because we are 95% certain there really are! This is a very simple test--just remember that if you calculate a χ^2 value and it is greater than the value in the table for that α and ν, you must reject the null hypothesis. This test can also be used if you have more than two categories.

The χ^2 one-sample test has certain limitations. If there are only two categories (df = 1), you cannot use it if either expected value is less than five (this means your sample size is just too small for the test to work). If there are more than two categories (df >1) you cannot use this test if 20% or more of the expected values are less than 5 or if any expected value is less than 1. If this happens, you need to collect more data. Or, there might be other tests you can use (see a statistics book), or you might be able to combine categories in a way that makes sense and gives you higher expected frequencies.

Two unrelated samples with nominal data: the χ^2 Two-Sample Test

Often you want to know if the frequencies of certain traits differ between populations. If your sample data are nominal, this is the test you need to use. It is similar to the χ^2 test we just learned, but it is not identical.

When two or more Lory species visit the same flowering tree, we may want to determine whether or not they are feeding in different parts of the tree. We divide the tree canopy into four categories (upper outside [UO], upper inside [UI], lower outside [LO], lower inside [LI]) and then count the number of visits by each Lory species to flowers in each zone of the canopy. Our H_o: there is no difference in the foraging patterns of the Lories (no difference in frequency of flower visits to each canopy category); our H_A: the Lory species forage in different zones (categories of the tree). This will be a two-tailed test, we decide on $\alpha = 0.01$ (just to be extra certain), and $\nu = 4-1 = 3$. Our example data:

	UO	UI	LO	LI	row total
Lory species 1	100*	70	50	40	260
Lory species 2	220	10	70	15	315
column total	320	80	120	55	575#

* number of flowers visited

grand total or N

To obtain a χ^2 value, we use the same formula:

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$$

But, how do we get the expected values? We must obtain an expected value for each cell. This is easy: to obtain E for any given cell, just multiply the cell's column total by its row total and divide by the grand total. For example, the expected value for Lory species 1 at UO flowers is

$$\frac{(320)(260)}{575} = 144.7$$

Just repeat this for each cell to get each expected value. When you are finished, for each cell subtract E from O, square the difference and divide by E. Add up all these results and you have your χ^2.

Here is an example:

	UO	UI	LO	LI	Row total
O	100	70	50	40	260
E	145	36	54	25	
O-E	-45	34	-4	15	
$(O-E)^2$	2025	1156	16	225	
$(O-E)^2/E$	14.0	32.1	0.3	9.0	
O	220	10	70	15	315
E	175	44	66	30	
O-E	45	-34	4	-15	
$(O-E)^2$	2025	1156	16	225	
$(O-E)^2/E$	11.6	26.3	0.2	7.5	
Col total	320	80	120	55	575

Now, to get χ^2 you just sum up all the $(O-E)^2/E$ values: 14.0 + 32.1 + 0.3 + 9.0 +11.6 +26.3 + 0.2 + 7.5 = 101. Now you just look this up in your χ^2 statistic table for df = 3 [df = (4 - 1)] and we see that our value is >> than the value for α = 0.001, which is only 16.27. Therefore we can reject the null hypothesis with 99.9% certainty [(1 – 0.001)*100] and say that the two Lory species do forage in different parts of the tree canopy.

If you only have 2 categories and 2 samples, you can use a shortcut formula. Say the four cells are termed A, B, C, and D, respectively:

A	B	A + B
C	D	C + D
A + C	B + D	A+B+C+D=N

then

$$\chi^2 = \frac{N\left(|AD-BC|-\frac{N}{2}\right)^2}{(A+B)(C+D)(A+C)(B+D)}$$

with df = 1. Remember that $|\ldots|$ are absolute value signs meaning that even if it is negative, use the positive value.

The same restrictions concerning expected values apply here as in the one-sample test. If your data are too few to do this test, there is a test called the Fisher Exact Probability Test that works for small samples. We won't explain this one, just know it exists and is in most statistics books.

More than two unrelated samples: the χ^2 k-sample Test

What if three or more Lory species had come to the tree you had divided into four spatial zones? You could test for overall differences in foraging patterns with a single test, the χ^2 k-sample test. It is performed in precisely the same way as the χ^2 2-sample test. You just determine expected values for each cell by multiplying its row total by its column total and dividing by the grand total. Again,

$$\chi^2 = \sum_{i=1}^{k}\frac{(O_i - E_i)^2}{E_i}$$

where O and E are the observed and expected value for a given cell. In this case, we have more than two samples, so we need to change our degrees of freedom: df = (number of rows - 1)(number of columns -1).

The Mann-Whitney U-test: Two unrelated samples with ordinal data

If we can give ranks or scores to observations, are interested in finding if there is a significant difference between the means of two samples, and do not have too many observations with the same score, we can use the Mann-Whitney U test. This test should be used a great deal more than it is, instead of the *t*-test. It is actually more powerful. It is easy too. For example, say that we work on two species of spiders, A and B, and want to know if one is more successful in terms of number of prey caught. H_o: There is no difference in the success of the two species' ability to catch prey. H_A: The species differ in their ability to catch prey. Test: two-tailed, α = 0.05 (we want to be 95% sure). We go out and sample 8 webs of A and 10 webs of B, and count the number of prey caught in each. We then rank all the observations from 1 to 18 (i.e. the web with the fewest prey is ranked 1...up to the web with the most prey ranked 18). Note that if there is a

tie, each of the tied observations gets the mean rank of the tied ones. For example if three webs had zero captures, each of the 0, 0, and 0 values would rank as 1, 2, and 3; the $\bar{x}$ of 1, 2, and 3 = 2, so all of the 0 values would get a rank of 2.

Say we obtain the following data: the number of prey in webs of species A = 0,0,0,1,2,2,4,9 and the number of prey in webs of species B = 3,3,5,5,6,6,7,10,11,15.

We rank them and sum the ranks for each species:

Species A		Species B	
No of Prey	Rank	No of Prey	Rank
0	2	3	7.5
0	2	3	7.5
0	2	5	10.5
1	4	5	10.5
2	5.5	6	12.5
2	5.5	6	12.5
4	9	7	14
9	15	10	16
		11	17
		15	18
$n_1 = 8$	$R_1 = 45$	$n_2 = 10$	$R_2 = 126$

Next we can calculate U:

$$U = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1$$

and

$$U' = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2$$

(or simply $U' = n_1 n_2 - U$)

Then choose the smaller of the two values, U or U', and turn to the handy U-table at the back of this manual (Appendix 3). If your U is smaller than the value in the table, you can reject the null hypothesis at that alpha level.

If you have a sample size that is larger than those shown in the table you will need to convert your U to z with the formula:

use U or U', whichever is smaller

$$z = \frac{U - \frac{n_1 n_2}{2}}{\sqrt{\frac{(n_1 n_2)(n_1 + n_2 + 1)}{12}}}$$

A z value greater than 1.96 or less than -1.96 is significant at $\alpha = 0.05$ and a z value greater than 2.57 or less than -2.57 is significant at $\alpha = 0.01$.

One complication in the Mann-Whitney U test is that if there are too many ties in ranks between samples (e.g., if two A spiders and three B spiders had each caught 3 prey), a correction must be made to the U formula. A statistical textbook will have this correction factor.

Kolmogorov-Smirnov 2-sample test: Two unrelated samples with ordinal data

If your data have lots of ties-- that is, if there are not too many different ranks and there are a lot of observations in each rank, the U-test should not be used, even with the correction factor. There is a test you can use, but it also tests for differences in dispersion of the data, as well as differences in the means. If you do not mind this (and I usually do not because it is interesting to know if dispersion differs), then the Kolmogorov-Smirnov test (KS test) is a good one to use. This test compares **cumulative frequencies** from the smallest to largest categories.

For example, when our two species of Lory visit the same plant we could tally the number of visits made by each species every hour to see if both species come to the tree at the same times. H_o: there is no difference in the timing of visits to the tree by the two species of Lory. H_A: There is a difference in the times that both species visit the tree. OK, you should recognize this as a 2-tailed test, let's set $\alpha = 0.01$. Collect your data and set it up in the following way (this is an example of why it is good to make good data sheets for your study-- you can go straight to your statistical tests if you plan ahead!)

Hour:	1	2	3	4	5	total
Lory 1	131*	177	116	23	167	$614=n_1$
Lory 2	42	226	406	160	156	$990=n_2$

* number of lories that visited the tree in that hour.

Next you calculate the cumulative number of visits (second line in table below) and then the cumulative proportion of visits (by dividing the

cumulative number of visits by the total visits) (third line in the table below):

no	131	177	116	23	167	n_1=
cum no	131	308	424	447	614	614
cum prop	.213	.502	.691	.728	1	
no	42	226	406	160	156	n_2=
cum no	42	268	674	834	990	990
cum prop	.042	.271	.681	.842	1	

Now you simply look for the greatest difference in the cumulative proportion (values in the bottom line of each cell) between the two samples (Lory 1 vs. Lory 2). In hour 2 Lory 1 made had already made 0.502 of its visits and Lory 2 had only made 0.271 of its visits (over half versus only one fourth). The difference in these two frequencies is 0.231. You can check the other cells, but this is the greatest difference. Next you need to calculate the KS value for our desired α level. If our greatest difference exceeds the calculated KS value, we will reject the null hypothesis.

Use these formulae:

For α = .05, the KS value is: $1.36\sqrt{\frac{n_1+n_2}{n_1 n_2}}$

For α = .01, the KS value is: $1.63\sqrt{\frac{n_1+n_2}{n_1 n_2}}$

In our example we calculate the KS value for α = 0.01, using n_1 = 614 and n_2 = 990. It comes out to 0.084, obviously far lower than 0.231. Thus we reject H_o and conclude that the Lories feed at different times with 99% certainl.

Note that this test reveals differences in dispersion as well as the mean. For example, Lory 1 may have fed early in the morning, rested in mid-day, and fed again later in the day, but its mean feeding time would be mid-day. Lory 2 may have rested in the morning, fed at mid-day (when the first lory was resting) then rested in the late day, but it would also have its mean feeding time at mid-day. So even though the means are the same, the dispersions are very different. A test for different means would not identify this difference, but the KS test does-- the birds have different habits even though the mean time of feeding might be the same!

Spearman-rank correlation: Relationship between two variables

The Spearman rank correlation should be used instead of parametric correlation any time either of the two variables is measured in less than interval fashion. It is also OK and even better to use the Spearman rank correlation with interval data sometimes. It is better to use Spearman rather than parametric correlation: if measurements seem erratic; if any of the assumptions of parametric statistics are invalid; or if there are one or two points that are far-off from the rest of the data (called **outliers**) that might just be freak happenings and which might strongly influence a parametric regression. For example, what if we are working with a single species of spider and wanted to know if those individuals with larger webs also caught more prey. If most of the webs had 1-5 prey items but one had 25 prey items, it would be an outlier and would throw off the parametric correlation test.

OK, let's proceed with our example Spearman Correlation Test. H_o: There is no relationship between web size and the number of prey captured. H_A: Larger webs catch more prey. This is a one-tailed test (do you see why?). Let's set α = 0.05. Can we do a parametric correlation? Many people would, but they would be incorrect to do so! One of our variables is measured on an ordinal scale (number of prey-- we cannot have 1.86 prey, it is either 1,2,3...n). Therefore we should use the Spearman rank correlation.

To obtain the Spearman rank correlation coefficient (r_s), first rank one variable (size of webs). Then rank the second variable (number of prey). [NOTE: do not rank back and forth between the variables like you did with the U-test, each variable set gets ranked independently—so you have a rank number 1 for web size and a rank number 1 for number of prey, a rank number 2 for web size and a rank number 2 for number of prey, etc.].

Next, determine the difference in the ranks (d_i) for each web (subtract the rank of number of prey in a web from the rank of the size of the same web). It does not really matter which you subtract from the other, just so long as you do all the data the same way (rank variable 1- rank variable 2, or rank variable 2- rank variable 1). But make sure you do not mix up the data—these are paired samples—a particular web size goes with the number of prey in that web, not in another web! Next square the difference (d_i^2). Next, sum the squares (Σd_i^2). Now, plug this value into the formula:

$$r_s = 1 - \frac{6\sum_{i=1}^{N} d_i^2}{N^3 - N}$$

Let's work through an example: say we measured eight webs and counted the number of prey in each, we set up the data and rank them as follows:

Web (cm^2)	**Rank For Web**	**No of Prey**	**Rank for Prey**	**d_i**	**d_i^2**
100	1	7	2	-1	1
120	2	9	3	-1	1
140	3	1	1	2	4
175	4	11	4	0	0
190	5	17	7	-2	4
210	6	15	6	0	0
260	7	12	5	2	4
280	8	22	8	0	0
					$\Sigma d_i^2 = 14$

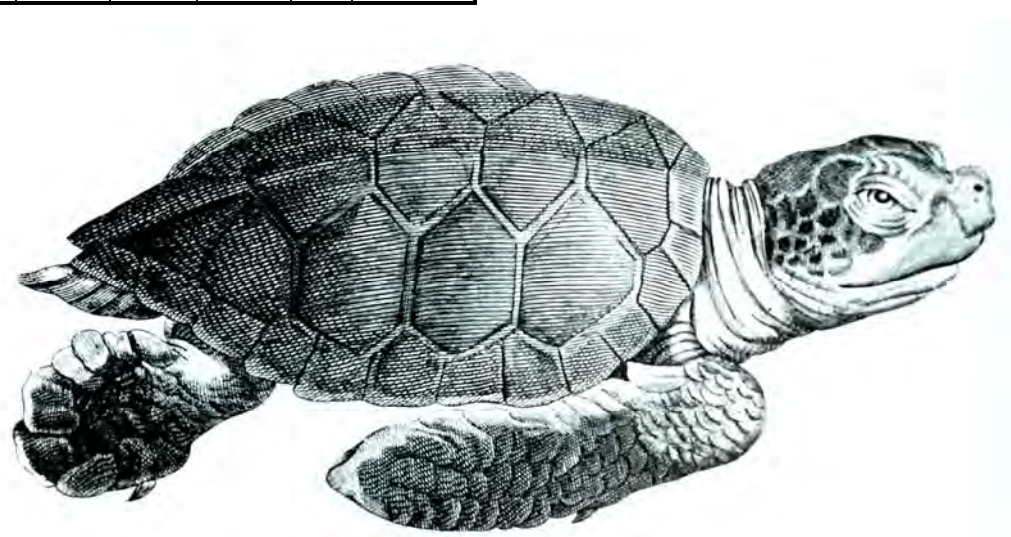
Then we use our formula:

$$r_s = 1 - \frac{6(14)}{8^3 - 8} = 0.833$$

To determine whether or not r_s is significant, look in the table in Appendix 3. In this case, the table says that for N = 8 pairs and $\alpha = 0.05$, $r_s = 0.643$ (one-tailed test). Our calculated value is larger than this. Thus we can reject the null hypothesis and accept H_A. We conclude that larger webs catch more prey.

If N is greater than the Spearman Table gives, we will need to convert r_s to *t* in order to determine its significance. Also, if there are very many ties in the ranks we need to make a correction to the formula given above. We won't go into these things, but know that you can find them in a statistics book if you need them.

Now you have the foundations for some basic statistics. If you use these properly when you write reports or do your research, no one will be able to argue with your results. And people will realize that you are a really SMART person! It looks like magic, but now you know the tricks!



CHAPTER 13: Proposal Writing

Introduction

The ability to write a good proposal is a very important skill for biologists and conservationists. If you master this skill you can obtain the money needed for your research and programs. If you cannot do this, even if you are a tremendous scientist, it will be hard for you to do your work without the funds you need to do it. In this training manual we cover many important skills. But proposal writing is the skill that will enable you to utilize the other skills you have learned.

Writing a good proposal serves two important functions: **1)** it enables you to raise the money and permission you need to undertake your project and **2)** it forces you to think carefully about your project and plan it thoroughly. A good, fundable proposal will only come from a person who has clearly laid-out their project in a way that will survive critical examination. Every good project should start with a well-written and carefully crafted proposal, even if you do not need to raise money for the project. If, for example, you already have money for a project you should still write a proposal that you will follow when conducting the project; it is your step by step recipe for what to do.

All proposals basically describe what you want to do, how you are going to do it, why you want to do it, and other details like when, how much things will cost, etc. Proposals are often submitted to ***non-profit organizations*** like foundations or charities. These organizations are dedicated to distributing money for projects they think are worthwhile. They are in the business of raising money to give away; they are prohibited by law from making a profit, so much of the money they raise is given to projects and people who have submitted proposals. Most non-profit organizations are ***non-governmental organizations*** (NGOs). That is, they are not part of the government and do not directly receive money from taxes. There are also ***governmental organizations*** that give grants for work, or allocate work as contracts or consultancies. The money for these grants would come from government funds like collected taxes.

Obtaining funds from any source requires good proposal writing skills. Governments should be particularly cautious about how they allocate money, since the money they give really belongs to the citizens and taxpayers. Thus, governmental organizations often have rigorous requirements for proposal writing. Additionally, you often need to write a good proposal to obtain government permission for various kinds of projects, even if you are not getting money from the government. For example you might have to apply for permission from the Department of Environment and Conservation to undertake your project, and will need to submit a proposal to them for approval.

Lastly, many commercial, for-profit organizations or ***corporations*** give funds in the form of grants, contracts or consultancies. Good proposal writing skills are essential for approaching these sources as well. After all, corporations wish to make a profit; they will not

casually give money away (because this reduces their profit) unless there is some clear benefit. ***Good proposal-writing skills enable you to design a better project, obtain the permission you need to undertake a project and enable you to raise the money needed for your project.*** Proposal writing is a very important skill for everyone working in science and conservation.

Funding institutions, whoever they are, generally have some interest in getting something done (e.g., a conservation project, certain research, a training workshop, etc.) and the money to get it done. What they lack is the ability to actually do the project themselves. You, as a trained scientist, have the interest in getting something done and the ability to do it. What you lack is the money to get it done. The purpose of your proposal is to find the right institution that shares your interests, but which lacks your capabilities. Your job is to convince them that you share their interest, and that you are the best person/organization to undertake the project.

Outline of proposal writing steps

The basic sequence for writing a proposal and obtaining a grant is given in the numbered steps below. Each of these steps is described in detail in this chapter.

1. Investigator explicitly identifies a research topic or conservation project.

2. Investigator makes a rough outline of the project: assessing the methods, the likelihood of success (feasibility) and a rough idea of the cost of the project. Beginning a pilot study is extremely useful at this stage.

3. Investigator researches potential funding agencies that might be interested in supporting the project and who can provide the type of budget needed.

4. Compose a query letter and send it to all of the potential funding agencies you have identified. Re-write the query letter for each agency, stressing why your project matches their mission and needs. (Don't send the same copy to each agency).

5. Continue developing your plans while you wait for a response to your query letter. Continue working on your pilot study during this stage; review the literature.

6. If an agency responds that it would like to receive your proposal, begin working on the formal proposal following their specified guidelines.

7. Have your proposal critically reviewed several times before submitting it.

8. Submit the proposal along with a cover letter. After submitting your proposal it will be reviewed by the agency. Different agencies have different reviewing procedures. It helps to know how a proposal will be reviewed when you write it. After being reviewed three things can happen: A) your proposal is flat-out rejected. B) Your proposal is accepted without change. C) Your proposal is provisionally accepted if you make certain changes. Outcome A is the most frequent, so do not be discouraged when this happens. It happens to everyone OFTEN! Outcome C is the next most likely, it can be frustrating to have them want you to alter your project, but usually they have good reasons for their recommended changes. You should be delighted with this outcome, as well as outcome B-- what we all hope for, but rarely get. Often with outcome C you will have to re-write your proposal and send it in again. Getting a proposal funded can be very time-consuming, but we hope you find it worthwhile.

9. If your proposal was rejected (Outcome A), you should read the reviewers comments or letter you receive to see why it was rejected. You should consider these reasons when you write the next proposal. Use rejections as a way to improve your proposal and your proposal writing skills. It often takes several rejections before you come up with a winning proposal!

10. If your proposal was accepted as is (Outcome B), immediately write a follow-up thank-you and indicate when you are ready to begin. Do not simply wait for them to send you a check.

11. If you are asked to revise your proposal (Outcome C), send them a note immediately

thanking them and indicate that you will submit a revised proposal soon (if that is what they have requested). Give their comments consideration and rewrite the proposal accordingly. If there are suggested revisions you do not want to make, you must explain very well why you do not wish to make them. Resubmit your proposal with a new cover letter.

12. Upon receiving funding or support, send a letter acknowledging receipt of the funds and thanking the agency.

13. Perform the project as described, modifying only as necessary. Meet all requirements for reporting expenditures and results.

Description of proposal writing steps

Step 1: Investigator explicitly identifies a research topic or conservation project.

Much of the training you obtain elsewhere in your career, e.g., in this manual or in school, is designed to enable you to identify scientifically important research. The purpose here is not to explain what sorts of projects you should identify-- that requires years of education and training. However, there are several important points that you should consider.

Before you begin to write a proposal, you should make sure it is something you are truly interested in doing. Even if the project is tremendously important and easily funded, if you do not have the desire to actually do it, and to endure through the difficulties you will encounter, you should not even begin to write the proposal. If a proposal is submitted and funded you have made an obligation to the funding agency. This usually is no problem and people are usually delighted when their proposals are funded. Most people do not go to the trouble of writing a proposal unless they really want to do a project. However, sometimes people are not so sure, and they write a proposal anyway, then find out they have committed themselves to something they do not really want to do. You should think of a proposal as a contract, and a grant as the agency's purchase of what you have promised in the contract. With a proposal you give the terms of what you will do in exchange for a sum of money (grant) or other service. When you get a grant the agency giving it does not see it as money they are giving away. They expect a return for the money, like paying for a service. Instead of returning the money, you return the product you promised in your proposal. Perhaps you promised a piece of research about bees, or a project in which trees are to be planted-- then this is what you must deliver. Whatever you proposed, that is what the agency expects.

Just as you would be cautious, agencies do not loan their money out to just anyone who "claims" they will perform a service. It is important that you have demonstrated in the past that you complete your proposals, that you finish your schooling with good grades, and that you have people who will support your application-- just as you would require from someone before *you* gave them money. Much of your behaviour in school and in your research plays a vital role in your ability to get grants; it is not just your proposal writing skills that are important. Your reputation and associates play an important role for you, so do not neglect to develop these too. If you lose your reputation, like you do not do what you said you would in a proposal, it is the same as if you did not pay back a loan. Other people will not loan you money once they hear you don't pay them back. Your integrity and reputation are extremely important-- you must develop these just as you might develop any marketable skill for a job. If you are perceived as lacking integrity, you will have a very hard time ever getting a grant. Finally, your future ability to raise money might be seriously handicapped if you obtain a grant or contract and fail to produce what you promised.

Remember, the people evaluating your proposal will not only consider the proposal you have written, but they will also evaluate you and your ability to do what is proposed. If you are an expert on the vegetation of the Sogeri Plateau and you propose to study bats near Wewak, the reviewers might think the project is great, but that

you are not the right person to do it! A good proposal is more than just scientifically correct-- it must be a proper match for you and for the objectives of the agency.

After you have evaluated your interest and ability to undertake a project, you can move ahead with the actual steps of preparing the proposal. The most important first step is that you should write ***explicit questions*** that your project will answer if it is a research proposal, and ***explicit goals*** you will accomplish if it is a project proposal. Once you have well-crafted questions or goals, the rest of the proposal is much easier. Well-stated questions enable you to design proper methods, proper analyses and statistics, and enable you to clearly communicate results. Poorly-crafted questions and goals doom a proposal and doom a study or project even if it is funded. With poorly-stated questions or goals your reviewers will not understand what you have in mind.

A poorly-stated research question might say: *"What happens when Markham Valley grasslands burn?"* This question tells us very little and does not suggest proper methods that should be used. It is too vague-- are you interested in the effects of burning on plant life? On insect populations? On soil nutrients? This question only suggests more questions. A well-stated research question will suggest methods and a research program.

An example of a well-stated question would read: *"What happens to soil invertebrate populations when the grasslands of the Markham Valley are burned?"* Immediately this question suggests a research project: sample insects from the soil in grasslands before and after burning, or from burned and unburned areas. This question gives the reviewer a framework to use when evaluating your proposal-- they can look at your proposal and assess whether your proposal is the best way to answer the question. Properly posing your question and goals is probably the most important step of proposal writing.

Another example of a poorly-stated project goal: *"Reduce deforestation."* This is a worthy goal, but it is so vague that it does not suggest a way of attaining the goal. Your goal should be stated in such a way that your proposed project is the best way to do it! A well-stated goal for the same project might be: *"Reduce deforestation around villages in the Chimbu highlands by providing village women with fuel-efficient pressure cookers."* Although the second goal encompasses the first, it suggests a clear way to proceed-- where you will work, who you will work with, and how this project will attain the goal (by enabling women to use less fuel for cooking, meaning fewer trees will be burned at mealtime).

Some more examples:
Poorly-stated: *"What happens when bats eat wild mangos?"*
Well-stated: *"Do <u>Pteropus</u> bats disperse the seeds of wild mango species (<u>Mangifera</u> spp.) in the Gulf Province lowlands?"*

Poorly-stated: *"Is road-building bad for fish?"*
Well-stated: *"What effects does silt run-off during road construction have on downstream fish populations?"*

Poorly-stated: *"Do old gardens grow back like landslides grow back?"*
Well-stated: *"How does the density, diversity and species composition of vegetation in abandoned gardens compare with equally-aged re-growth in natural landslides?"*

Poorly-stated: *"How much hunting is bad for cuscus populations?"*
Well-stated : *"What are the long-term consequences of varying harvest rates (hunting pressures) on cuscus populations within the lowland forests surrounding Popondetta?"*

All of the above examples should demonstrate to you how a poorly-thought out question only suggests more questions, whereas a well-worded question makes you think of ways to get at the answer. If the reviewer thinks of ways to get at

the answer and you describe similar methods in your proposal, you are well on the way to having your proposal funded! Remember, it is important not to have too many questions or goals for a single proposal. If you try to do too many things at once you risk finishing none of them. It is much better to attempt a limited project and complete it successfully than to try to do much and fail at all of it.

Step 2: Investigator makes a rough outline of the project: assessing the methods, the likelihood of success (feasibility) and a rough idea of the cost of the project. Beginning a pilot study is extremely useful at this stage.

Once you have an idea that you are interested in pursuing and which you think you can do, you should next make a rough outline of the project. In your outline sketch out the methods you will use, where you will do your project, and how much time you will need. As you do this, evaluate your outline against your stated objectives. If you are going to be studying how gardens re-grow after being abandoned, you must identify which gardens, how many gardens, large or small gardens, highland or lowland gardens, etc. Design your methods so they meet your specific goals-- if it is difficult to do this you should make your goals more specific as you go. For example, you might want to modify your question to refer solely to small kaukau gardens-- then this makes your method for choosing study gardens easier and more explicit.

As you outline your methods you must also assess the feasibility of your methods. Sure, it would be great to study re-growth in 100 small gardens, but this probably would not be possible for you to do. It is vital that the methods you propose seem reasonable and feasible to the reviewer. The best way to do this is to undertake a small pilot study.

A ***pilot study*** is a short model of the entire proposal. In a pilot study you try out as many of the methods you propose to use as possible. By doing a pilot study you can learn if your methods really work, how long it really takes to use your methods, and how much money you will really need. Your pilot study will enable you to quickly find out what the problems are in your design and will allow you to fix your proposal before it is reviewed. Reviewers of proposals are often more familiar with your topic than you are; they are likely to spot problems you will miss unless you do a pilot study first. For example, in your proposal to study garden re-growth, you might say you will tag all the seedlings in a one hectare 3-year old garden in four days. A reviewer might know that this cannot be done, knowing that it will probably take ten days to do this. Additionally, sometimes the reviewer might think something is a problem that actually is not. If you have done a pilot study you can demonstrate that it actually is not a problem. For example, the same reviewer might change his mind if you can show that you actually did go out to a garden and tagged all of the seedlings in four days! Trying your methods in a pilot study ensures that you can really do what you propose to do. Otherwise it is just up to the reviewer's assessment of your abilities.

The pilot study enables you to make a realistic budget as well. If you ask for 260 Kina for tree tags a reviewer might think this is too much money. But if you show that you needed 10 Kina to tag trees in one garden and you plan to tag 24 gardens, then they cannot think 260 Kina is too much money (it is good to budget a little extra)!

A pilot study also gives you preliminary data that you can show in your proposal. If you are comparing garden re-growth and landslide re-growth, your pilot study data from one garden and one landslide might suggest some interesting differences and/or similarities. Of course, one of each is not a large enough sample to say anything conclusively. However, it is enough to show that something interesting might come out of your study, and that it should be funded so you can really learn what the differences and similarities are. It is enough to intrigue the reviewers.

Lastly, a pilot study demonstrates that you are truly committed to doing your project. Doing a pilot study on your own time tells the

reviewers that you are serious and determined. Agencies feel safer giving money to a project that already has a pilot study completed because the pilot study not only shows the methods are good, but that the person doing them is a good risk. Undertaking a good pilot study is one of the best strategies to getting your proposal funded. You should give a lot of thought to designing and doing pilot studies as you write your proposal outline, and you should keep developing your ideas right up until the time you actually begin a project! The better you refine your ideas and methods before you formally begin, the better your project will go once you begin. You should have a **very** good idea of how to proceed by the time you start. If you do not, you are probably going to do a poor job.

Step 3: Investigator seeks potential funding agencies that might be interested in supporting the project and who can provide the type of budget needed.

As you develop your plans you should be looking for potential funding agencies if you do not already have one in mind. There are many possibilities and the more you try the better your chances of funding. You should talk with your friends, professors, employers, school administrators, reference librarians, etc. and ask them if they have any ideas for sources of funding. As you study your subject you will be reading many research papers about your topic. You should read the "Acknowledgments" sections of research papers and note what organizations have funded studies and projects similar to the one you will be proposing. Keep a file of any potential funding agencies as you go through your career.

The size of an award depends on the particular agency more than on what kind of agency it is (NGO, government, corporate). Some give grants of only a few hundred kina; others fund projects that cost millions of kina. Those that give small grants clearly aren't going to fund expensive projects. Likewise, agencies that usually fund expensive projects often do not have time to consider proposals for just a few hundred kina. So, you must identify agencies that consider proposals in your budget range. Similarly, agencies have different priorities. Some fund rural development, some support health care, and some support ecological research. You do not want to ask an agency that supports health research to grant your study of damsel fly biology. Therefore, you must also match your proposal to the right sort of agency. We will discuss this more below. Many people write excellent proposals, but they fail simply because they have not sent them to the appropriate funding agency.

Many overseas organizations are very interested in supporting PNG nationals in conservation. They see it as necessary to have nationals involved in their own conservation programs, not just expatriates. Thus, there really are many opportunities for you to raise grant money. You probably are not aware of them all, because many of the potential agencies are based overseas. Please believe us when we tell you that there are opportunities for students who work hard, excel and sincerely wish to work in conservation and biology. The authors of this manual and the instructors in your training course are eager to help you connect with overseas agencies. For students who work hard, are enthusiastic, and do well there are many opportunities for an exciting and challenging career, and to do something really significant for Papua New Guinea.

Step 4: Compose a query letter and send it to all of the potential funding agencies you have identified. Re-write the query letter for each agency.

A ***query letter*** or ***letter of interest*** is not a full proposal, but instead is a brief introduction of yourself and the project you would like to propose. The query letter should be very brief and to the point. The idea of a query letter is to save you and the agency time. It saves you time by not having to write a full proposal for an agency that is not going to fund your project because they have different goals. It saves the agency time by not having to read proposals that are not their sort of project. So, keep your query

letter short and to the point. The query letter enables you to find the most likely agencies to fund your project without having to write dozens of long proposals.

Your query letter should briefly introduce who you are and where you stand in your career. For example: *"My name is Fred Blatz and I am a 4th year student at the University of Papua New Guinea."*

You should briefly state why you are writing (they do not automatically assume you are sending a query letter). For example: *"I am about to begin my honours research project and am writing to inquire regarding the possibility of obtaining financial support from your* _____ (foundation, corporation, etc.) *to support my proposed research."*

You should very briefly state the problem or issue you plan to study. For example: *"Flying foxes are among the largest mammals in PNG. They are very numerous in some parts of the Gulf Province where they consume large quantities of fruits from rainforest trees. I intend to study the role these bats play in dispersing the seeds of wild mango species. Wild mangoes are a common tree in the lowlands of Gulf Province."*

You then should briefly state the methods you intend to use and give some idea of the scope of the project. For example: *"I will collect wild mango seeds from under bat roosts and plant them in a shade house where I will compare their germination and growth to wild mango seeds that were not dispersed by flying foxes. This study will require roughly six months of field work."*

You might follow-up with a statement about why this project is interesting or important. for example: *"Flying foxes are heavily hunted in many areas of PNG, including Gulf Province. It is important to understand if the seed dispersing activities of these bats are important for the regeneration of rainforest trees like wild mango in order to justify regulating the hunting of bats."*

Once you have briefly introduced yourself, explained your project and given some idea of the project's aims and scope you should make the query about obtaining money. Simply ask them if this is the sort of project they would be interested in supporting. For example: *"I am hoping to obtain roughly 3000 Kina to support this six month study. If this is the sort of project you might like to support or partially support, I would be delighted to submit a formal proposal explaining the project in detail."*

Then follow with a request for more details about their applications procedures. Some agencies have forms you must fill out, some have page limitations, and some have other specific formats they require. You will need to know these if you are going to write a winning proposal. For example: *"If you are interested in a full proposal from me, please send me your application guidelines and any information or forms that might be needed for submission."* If you already have some support for your project but need more money, it is a good idea to mention this. For example: *"The University research fund has already granted 500 Kina to support this project; I am seeking to obtain the additional 2500 Kina I will need to finish the project."* Facts like this will make your project appealing, and so are worth mentioning. It says that someone else has confidence in your ability and in the merit of your question. If you can elicit a lot of interest with your query letter you are off to a really good start!

Close your query letter with a polite thank-you, a request for help finding funding if they are unable to help you, and specific details about how they can contact you. For example: *"Thank-you for considering this request. If this project does not fall within your funding priorities, I would be grateful if you could suggest any other potential granting agencies I could approach. I look forward to hearing from you and hope you will find my proposed project noteworthy. Sincerely, Fred Blatz, address..... phone.....email....."*

Try to send as many query letters out as you can. Do not just write the same query letter (photocopies) to each agency you try. Sometimes an agency might forward your letter to someone they think would be interested in your project. It does not look good if they already received the same identical letter from you. Try to design

each letter for that particular agency-- it only takes a few minutes more and with a word processor you can do it really fast.

Do not be discouraged by negative responses! A negative response does not mean your project is not good or interesting, it usually just means that the agency you sent the query to funds different sorts of projects. Someone who normally funds research about bats is not likely to fund a project to study insects in burned grasslands. Remember, KEEP TRYING. If you really think your project is good and worthwhile, eventually you will find an agency that thinks so too! If you show your enthusiasm for your project, they will get enthusiastic also!

Step 5: Continue developing your plans while you wait for a response to your query letter. Continue working on your pilot study during this stage; review the literature.

Do not sit down and just wait for responses to the query letters you send out. Keep developing your ideas. Work on pilot projects. Try out your methods. Get some preliminary data. Review as much literature as you can find. If you are unable to get the literature you need, contact your former instructors (like the teachers of this course and authors of this manual) and request their help from libraries overseas. The more you have prepared, the better your final proposal will be and the more quickly you will be able to write it. When you get an indication of interest from one of your query letters you will want to follow-up quickly, with a good full proposal. You will find that if you work very hard and stick with it you will get many opportunities to do the kinds of projects you want to do. It takes a lot of initiative and motivation. If you hope to get a job where you sit behind a desk and someone tells you what to do every day, you should not be learning to write proposals. But, if you have good ideas and want to make them happen you *should* be learning to write proposals. It is hard work, but we think it is better than simply being told what to do all the time!

Step 6: If an agency responds that it would like to receive your proposal, begin working on the formal proposal following their specified guidelines.

When an agency indicates that they would like to see your formal proposal they will send you some idea of what your proposal should look like. They might tell you how long it should be-- some places want just two pages, some want twenty. They might send you a form that you should fill out. If so, photocopy the form and practice filling-out copies before you make a final version on the form. Whatever they suggest, pay close attention. They will not be pleased if they specify a four page proposal and you send eight pages, no matter how good your eight pages are. The reviewers have a big job and often must read many proposals. It makes their job easier if everyone sticks to the rules and it only makes you look bad if you break the rules. If you are unclear about what your proposal should be like, you can call, fax or email them to inquire. Make a list of specific questions to ask in this communication before contacting them.

Often there is a deadline for submission. This means any proposals not received by the deadline will not be considered until the next review period. In many cases, proposals are reviewed just once or twice a year, so if you miss a deadline you might have a 6-12 month wait before your proposal will even be considered. Don't miss deadlines.

The proposal is where you must practice your best writing skills. Remember, this piece of paper will be critically examined, and if anything is unclear, poorly-written, or misleading it will damage your chances of funding. Work extremely hard on the proposal-- after all, this is a piece of paper that is worth however much money you are requesting!

Your proposal should introduce your subject with some background. Include enough references to the literature to indicate you have mastered whatever has already been published on the subject. Note: the extent to which you review the published literature will depend on the guidelines of the agency. In a short proposal you

might only have space for a very brief reference to the literature; in a long proposal you might be expected to critically review the literature and indicate how your study augments or improves what is already known.

In the introduction to your proposal you should indicate why the project or research is important in the broader context. How will your project benefit PNG? How will your research improve our knowledge? How can the data from this project be applied towards subjects that interest a broad range of people? Agencies want to perform a service to a broad range of people when they give a grant. It is not enough if your research will interest you, they want to know how it will interest other scientists and/or conservationists. A good grasp of the literature will help you address this need in your proposal. If you have read papers where authors have said it is important to measure soil nutrient loss after brush fires, then refer to them when you propose to study fire ecology in PNG grasslands. Good science has applications beyond a specific study site. In your introduction state how your study will relate to the general body of knowledge in the scientific or conservation "community."

After introducing your subject adequately you should describe your project and the methods you will use. The agency gives you money to accomplish a goal (stated in your introduction). They will want to see a detailed description of your methods. This is what enables them to evaluate your chance of successfully accomplishing what you want to do. You should have clearly-planned methods that you explicitly describe, paying as much attention to detail as their guidelines (proposal length) allow. The reviewers will evaluate if your methods will lead to the desired result. If your methods are flawed, they will not risk giving you the money. It is just like a loan-- you might not loan money to someone to start a business if they show a bad business plan. If their business fails, they can't repay you. An agency will not give you a grant if you have a bad plan; you won't be able to deliver what you promise. A good statement of methods is probably the most important part of the proposal, along with your reputation for integrity. The methods section will be much better if you have already done pilot studies and can prove that your methods do indeed work.

A good addition to your methods is a timeline. A ***timeline*** shows on a calendar how your project will proceed. The timeline shows when each phase or step of a project will begin and end. This enables the agency to evaluate your action plan-- have you scheduled enough time for set-up? Enough for data collection? Enough for data analysis? How often will you be in the field? A timeline shows how you and other people on a project will be occupied during the study/project duration.

After you have described your methods it is a good idea to conclude with a summary, particularly for a long proposal. In your summary briefly re-state the questions or goals you wish to address. Then emphasize how your methods and this proposal will meet those goals. And why those goals are important. Remember, the granting agency reviews many more proposals than it can fund. So, you want to conclude with a strong summary. Try to make them think: "this is an interesting/necessary goal and this is the project to get it done and this is the person to do the project." Emphasize the strengths of your proposal and emphasize your strengths as an investigator or project director.

The last part of the proposal is the ***budget***. Clearly state all of your predicted expenses and stipulate which ones you are asking this agency to cover. Set your budget up on a page with the description of an item on the left, the expected cost on the right and a requested total at the end of the list of expenses. The budget enables the reviewers to assess just how you plan to spend the award. You should show how much will be needed for all supplies, for wages, travel, lodging, etc. Do not simply request a flat amount for a project without showing how the money will be spent. If you get the award you will need to stick to the budget you gave the agency, so be very careful in compiling it. Make

sure it is accurate and you have what you will need in the right categories and for the right amounts. Many agencies require that you produce receipts to show just how you spent the grant. If you cannot do this, or if you have spent the grant very differently than you proposed, you could be in legal trouble. Certainly, you will develop a reputation as a bad risk for future grants.

Finally, if your budget is large you should give a ***budget justification***. In the justification you show why you predict certain expenses. For example, if you budgeted 800 Kina for travel to and from Rabaul, you should justify this with the latest quotation on ticket prices from Air Niugini. If you request 2000 Kina for field equipment, you should provide the prices given by your planned vendors. If you ask for K1800 for food you need to say this is based on K20 per person for 3 people over 30 days. You do not want the reviewers to think you just made up the numbers in your budget. Also, a budget justification shows that you have given serious thought to planning your proposal.

Step 7: Have your proposal critically reviewed several times before submitting it.

When you think you have finished your proposal, you have not! When you finish, you should give it to someone else to read; someone who has excellent writing skills and is preferably experienced in your field. This person should act like they are your reviewer and critically examine your proposal. They should tell you what parts are unclear or misleading, they should correct grammatical errors, and they should suggest ways to improve your proposal. This is a very important stage of all writing. By the time you have completely written a manuscript or proposal you have spent a lot of time looking at it. YOU know what you want to say, YOU know the important points to be made. Consequently, YOU cannot read the writing in the same way a stranger (the reviewer) will read it. You NEED someone to read your writing who is reading it for the first time. If they read it and it makes good sense to them, and they do not find any mistakes, then you are ready to send it in! But this is unlikely. You *want* them to find your mistakes-- it is better if your friend finds mistakes than if the agency's reviewers find them.

Do not give your writing to a friend if that friend is going to be shy or reluctant to be critical of what you have written. You want someone who will be ruthless and completely honest. The reviewers for granting agencies are very critical; your reader should be equally critical. This stage vastly improves the quality of your writing, and thus vastly improves your chances of getting a project or grant.

Likewise, do not be hurt or feel bad if you get a critical review from your readers. It is not a personal attack. EVERY writer has editors, they are absolutely necessary to produce good writing. Even if you look at the books written by the world's best writers you will see that they had editors. Nobody writes as well on their own as they write after good editing. Do not be angry or upset if your writing is criticized. Your instructors and the authors of this manual have all had their writing severely criticized many times. Sometimes it is difficult to have something you have worked on very hard be strongly criticized. BUT, if you fix it, the next reader will find less to criticize. After several repeats of critical reading, your proposal or manuscript will be excellent. It is a difficult step, but it truly does help.

Often agencies want a copy of your ***CV.*** The c.v. stands for ***curriculum vitae***, a Latin phrase meaning "life plan." This is essentially the same thing as a Resume. There will be books in the UPNG library that can help you make up a good CV. Your CV should include basic information about you like your name, address, phone number, email. It should also include a history of your education: where you attended school, university, or any additional courses you have taken (like this training course). You should state what your grade-point average was, any awards you received, and other pertinent educational history. You should list your relevant work experience and any unpaid work you have

done (like working as a professor's laboratory assistant). It is okay to include a brief summary of your duties for different jobs you have held, but don't go into tedious detail. You should list any reports or publications you have written. Your CV should end with names and the means of contacting several people who can give you a strong recommendation. Keep your CV short. It should not be longer than a couple of pages with additional pages if needed for your publications and references.

Step 8: Submit the proposal along with a cover letter.

Now your proposal is ready to submit. Send however many copies the agency requires along with a cover letter. The cover letter should briefly explain who you are, what you are applying for, and should state that your proposal is enclosed. The cover letter should include information on how you can be contacted (address, fax, phone and email). Again, in your cover letter you should indicate your enthusiasm for the proposal. Address the proposal and cover letter to the proper person according to their earlier response to your query letter.

Once you have sent in your proposal, celebrate! Submitting a proposal is a major accomplishment. Now you can only wait and follow the last steps **(steps 9-13)** listed above. Remember: accepting a grant is like signing a contract. Be sure to do what you proposed and stick to your budget if you get a grant. If you do, you will greatly improve your chances of getting another, maybe larger, grant in the future.

CHAPTER 14: How to Write a Scientific Paper

You should re-read this chapter every time you set out to write a scientific paper until you have done it a few times and are familiar with the process. Even a simple oversight could stop your paper from being published, so make sure you get it right before you submit it to an editor!

No matter how good your research is or how brilliant your wisdom, it means virtually nothing if it is not published and distributed. Proper communication is a crucial partner in every scientific endeavour. You should think about how to communicate the results of your research from the inception of your plan. If you develop the skill of communicating what you learn you will be more successful, more influential, and will develop a reputation so that donors and colleagues will want to support you.

There are many ways to communicate results, but several are ineffective and almost no different than not communicating at all. The mass of reports and documents that go unpublished we call "gray literature." In PNG a massive amount of information is locked away in grey literature. These are in-house reports for organizations, government offices, etc. that are not published and are poorly circulated. Often they become lost as soon as they are finished. If you work for months on a project and produce only a grey literature report that is lost, you have basically wasted those months.

Unpublished reports ("grey literature") are so numerous because they are easy to write-- they do not go through a stage of editing and peer-review like a published scientific paper. Many people take the easy way out and just knock off a report and give it to the office and feel they've met their obligation. Maybe they have for this contract or job, but they have done little to promote their career or to improve the knowledge in their field. You can always write your report to please the office and *then* write a REAL scientific paper and publish it afterwards. Then the entire world will have access to your science!

There is a growing trend to post gray literature on the web in the mistaken notion that this is publication. Posting on the web can make a report somewhat more accessible to the scientific community, but it still bypasses the essential steps of peer review and editing. An unedited report on the web only allows more people to see a bad report. Also, as thousands of reports are posted on the web, they still become "lost" among the millions of documents now accessible on the web. For example, I just checked the web for things about mammals in PNG and came up with 6,100 hits. If your report is in there at number 1679, do you think people are really going to find it? Most people only look at the first 10 or 20 results of a web search.

There are different kinds of scientific papers, like review papers, or critiques, but here we describe the main type of paper-- one that presents original data. We will first describe the basic structure of a good original paper, and will then give you some tips on how to write a good paper.

The basic components of a scientific paper are:
Title
Abstract
Introduction
Methods
Discussion
Acknowledgments
Literature Cited
Appendices

Title

The title of a scientific paper should be as explanatory as possible without becoming exceptionally long. If you work with a specific taxon, you should name it explicitly and use the appropriate scientific name. For example, if you studied the Raggiana Bird of Paradise, you can use that common name but be sure to also include the scientific name *Paradisaea raggiana*. Describe the activity you carried out-- a census, a life history study, etc. And try to give something about the locality, all in one title. A good way to learn how to create a good title is to look at titles of papers published in top journals.

The title should enable a reader to know what the paper is about and it should catch the reader's interest. Most readers simply scan titles to decide which papers they want to read. If you have a poor title, quite possibly many readers will ignore your article. Remember, the readers have no idea what you did or where you did it, so your title should at least get those ideas across. You do not have to state your results in your title-- you want to raise the reader's interest so they'll read on to find out the results.

An example of a poor title: *Frogs in Papua New Guinea*

An improved title: *Descriptions of the life histories of four species of New Guinea frogs (Microhylidae)*

An example of a poor title: *A study of seedlings on slopes*

An improved title: *Ground slope and topography affect seedling establishment: a study in montane Papua New Guinea*

From these examples you should be able to get an idea of what constitutes a good title. You should read through the titles on the cover page of any journal-- which ones strike you as interesting? Which ones look dull or vague?

Abstract

Most journals require an abstract for a paper. An abstract is a concise, one-paragraph summary of your entire paper. Because it is a summary, it is written last, after the rest of your paper. Because an abstract is so short, but needs to cover so much, it is often difficult to write a good abstract. They always require multiple stages of re-writing. Usually you write your first draft and then edit it many times to make it shorter and shorter until you cannot remove another word.

The abstract should be able to stand alone. Indeed, often the abstract of a scientific paper is cut away and posted independently in things like Biological Abstracts. This is a journal and web service that lists all abstracts of all biological papers being published and is used as a research tool. Researchers use this to find the papers they want to read among the thousands that are published every year. Thus often the only thing people will see or read is the abstract of your paper.

Generally an abstract has about 1-2 sentences stating your explicit question and relating that to the broader field, followed by 1-2 sentences stating the methods. You do not have to go into great detail on the methods, but do give the reader a good idea of how you got your results. Next the bulk of the abstract comes, with maybe 2-4 sentences giving your basic results. Then you conclude with 1-2 sentences of discussion stating the implications of your study or tying your results to a broader subject area-- show the link that will interest a broader range of scientists.

Do not conclude your abstract with non-informative statements like *"implications of the results are discussed in the paper."* We already assume you discuss your results in the paper-- and it does not tell the abstract reader anything.

Instead indicate what the implications are, e.g., *"these findings suggest large-seeded plants may not regenerate well in logged forest."*

Do not put citations in your abstract, since the abstract is often separated from the rest of the paper the abstract reader will have no way of knowing what (Dufus 1998) refers to.

Often journals will also want a list of keywords to go with the paper. These are single words or phrases that indicate important components of the paper. These are words your paper will be cross-referenced to, so people can search using those words and immediately be referred to your paper.

So the abstract gives a very succinct summary of the entire paper. Most people look at the abstract and title to decide if it is worth their time to read the rest of your paper. So you need to make the abstract and title as interesting as possible. Also, many people will only read your abstract, and not your entire paper, so you need to get as much information into is as possible.

Introduction

The Introduction is where you set the stage for the study you have done. You introduce the general topic and give a brief overview of the research that has already been published on that topic. Then you lead into your explicit question and how that relates to the overall subject you began with. After clearly stating the problem your research addresses, you can make predictions of what you think your research could reveal. Finally you can introduce the broader implications of your study. This is the section, along with the discussion, that requires a thorough knowledge of your subject matter, not just your own study. The methods and results are largely yours, but the introduction includes a lot of work published by other people.

The Introduction is important because it sets up the rest of your paper. From reading the introduction, it should be clear to the reader why you are doing the study—what it will add to our knowledge. The introduction states the objective of your study, and knowing this, the reader can then understand why you are performing the methods you describe. The introduction tells the reader where the paper is going, but without saying the results you will get. The introduction essentially assumes the experiment has not been done yet. For example, you might say "*it is important to know if bees pollinate mangroves in order to manage mangrove forests.*" This sets up a study of pollination of mangroves. Even though by the time you are writing the introduction you might know that it turned out that bees were not important, if this is what you were testing, you need to state it in your introduction. Also, if you give away too much of your results in the introduction, there is no point in reading on. Don't make this mistake. Write the introduction as if you wrote it *before* you started your study. Often, if you wrote a good grant proposal before starting your study, you can use parts of the proposal in the paper introduction.

The introduction should have literature citations for the factual statements you include, unless they are common knowledge, and for your review of the current state of knowledge. You can improve your ability to know what does and does not require a citation by examining when others use citations. ***Remember: One of the best ways to learn how to write a good paper is to read lots of journal articles and see how other people do it!!!*** Proper use of citations can greatly reduce the length of your paper in general. For example, instead of fully detailing some complicated thing, you can provide a less detailed description with a citation that leads the reader to a more thorough description. For example, you could say *"Hymenoptera are known to make at least 32 kinds of paper nests (Wilson 1987), but I will only be studying those making nests on the undersides of palms."* You didn't have to describe all 32 kinds, but you introduced the great diversity of nest types, and you showed the reader where to look for more information if they need or want it. With citations it is always best to cite mainstream, peer-reviewed journals that other readers can easily find. Whenever possible avoid citing things from in-house reports or other gray literature.

Whenever possible avoid citing unpublished sources, personal communications, or your personal, unpublished data. The point of a citation is to enable the reader to go see the source and judge it for themselves. Many journals will not even allow you to cite unpublished material. Can you see why it is so important for you to publish properly? People cannot and should not cite your work if you have not published it!

Methods

Beginning scientists generally write far too much for the methods. You should read lots of papers and get a "feel" for the content of a good methods section. The methods should explain what you did well enough that a reader can exactly replicate what you did. An important criterion of good science is that it can be replicated. If the methods described do not enable replication, it is not good science. But the methods also need to be as short as possible, concise, so you need to get all of the information in without wasting words. Do not say "*I measured the temperature with a blue thermometer that cost K5.43.*" We all know that you need a thermometer to take a temperature and who cares if it was blue or red, just say "*I recorded the temperature to the nearest 0.1 degree C.*" The second sentence is shorter and gives the reader more important information.

The second and most important use of the methods is to enable the reader to assess the quality of your data. They need to know enough to be reassured that you have not introduced bias in any form. They need to know how many replicates you have sampled in order to judge your statistics. They need to know if you have properly randomized where that is called for. They need to know if you have controlled for any source of error. All of this information needs to be incorporated into your methods, so that the critical reader can evaluate the quality of your data.

As with citations in the introduction, proper citation of methods in a scientific paper can greatly reduce the detail you must give. For example, if there is a fairly complicated, yet standard method you used, you might reduce the length of your methods section with a citation: *"DNA was isolated and separated by the process of density gradient centrifugation (Jones1988)."* If this is a fairly complicated method often used, you do not have to describe it completely, so long as you closely follow the methods Jones described in 1988. When you have a new method of your own design, then you need to describe that in greater detail.

In the methods section you should include a description of your study area if you are doing a field study. Give whatever detail is relevant to your study-- describe the habitat, vegetation, rainfall, location, elevation, etc. Sometimes a citation to another paper that describes the same study site or habitat can be sufficient.

If you have a complicated experimental design or one where you are testing several different hypotheses, you can break the different methods up with discrete headings. For example, this chapter has headings for title, abstract, introduction, etc. Do not just run a bunch of complicated and different methods together in one long description. Then when you report the results, you can use the same headings to organize your writing. For example if you are looking at the effects of temperature and humidity on the behaviour of a snail, you can have a section in the methods for temperature and a different section for humidity. Then in your results, you give your data in separate sections for temperature and humidity as well. This helps the reader a lot. Avoid running together unrelated topics or methods without a clear break between them. Use the same sub-headings in your methods, results and discussion sections, and in the same order. This is called using parallel structure.

So the methods section should be as short and concise as possible while allowing the reader to assess how you collected your data and enabling another scientist to replicate your study. By organizing your methods properly, you also have a template for organizing your results and discussion.

Results

In this course you will be asked to write results sections for several projects. The results section is just that-- results. The mistake most beginners make is to include too much about methods or discussion in the results. Do not interpret a result. If two populations are different you simply write: "*Population A differed from population B in mean body length* (statistics to back up the statement*).*" Do not say why you think they differed—that goes in the discussion section, just say that they differed and give the relevant statistics to back up the statement.

The results section is where you include all of your tables and graphs. Each table and graph is numbered and their number should be in the order they appear in the text. For example you could write: "*There was a positive correlation between temperature and humidity (r = 0.9, n = 56, P < 0.05, Figure 1), but no relationship between temperature and rainfall (r = 0.2, n = 64, P > 0.2, Figure 2).*" You almost always place the supporting statistics with the statement, in parentheses, in the same sentence. The only exception is when you include them in your graph; then you can simply cite the figure to substantiate your statement. See the section about tables and figures for more information about these important parts of your results section.

Usually you begin the results section with basic summary information including your sample size, mean, standard deviation and range. For example *"In twelve days of searching we found 42 butterflies with an average mass of 31 mg (SD= 1.2, range 28-35)."* Then you might go on to report the results of statistical tests undertaken with those 42 butterflies: *"More blue butterflies were found in gardens than in forest (X^2 = 7.5, df = 2, P < 0.05)."* If you measured many things, it often makes it shorter to present all the summary data in one Table, and then just refer to that, instead of listing lots of numbers in the text.

The standard formula for reporting statistics from a statistical test is in parentheses with the statistic first, the sample size and then the P (probability) value. For example to report the results of a t-test you would write something like this (t = 4.56, n = 32, P < 0.05). We'll go over this in class, but get used to writing statistics like this-- in this example you calculated a t statistic of 4.56, your sample size was 32, and there was a less than 0.05 probability that the difference you observed was just sampling error. Often for each statistical test you perform you give a single informative sentence with the outcome of the test and the essential statistics.

In this course we will give you a lot of examples and you will do a lot of statistics. But there is more to learn than what we have the time to give you—again, the best way for you to learn is to examine how results sections are written in good journals.

Results sections are exceptionally short and to the point-- just the facts, just the statistics. Keep it very brief. You can talk about it in the next section!

Discussion

OK, at last here's where you get to talk about things a little, and you can have a little leniency. Methods and results are totally factual with little room to insert your knowledge of the topic. Here in the discussion you interpret your results. As you interpret them you can refer, when convenient, back to the tables or figures in the results section, but you should not introduce any new figures or tables in the discussion unless they are only to compare your data to the literature and are not meant to introduce new results from your study.

It will help to organize your discussion in the same sequence as you described the methods and presented the results. Similar sub-headings will help keep everything organized. Now say what you think your results mean. If two populations were different, Why? If there was a correlation, Why? Give explanations about what you think is going on.

In the discussion you want to relate your findings back to the introduction-- if you predicted something in the introduction, now

you discuss whether your data support or refute the prediction. Here you will want to relate your findings to the citations you made in the introduction. Also, you should bring in more citations and relate your results to other studies and the broader field you are studying. Mention interesting things about your results and relate them to topics that will interest the reader.

In the discussion section you can discuss why methods worked or did not work. You can make suggestions for future studies. You can discuss the implications for conservation or other implications. You can recommend policy changes or recommend what other researchers should look into next. You can even speculate a little about what is going on, or what could happen under other conditions. For example, you could speculate about how global warming could affect your study system. Do not blather on and on and bore the reader. Instead, interest the reader and convince them that your results are indeed worthwhile. This is the section that requires the most knowledge of the field you are studying. A technician can write the methods and results, but it takes a well-versed scientist to write a good discussion. As you research for your proposal and introduction, keep notes to include in the discussion section. Do not leave experimental results unexplained or un-interpreted. If you mention something in the introduction, methods, or results it requires some discussion in this section, even if it is only a very brief statement (e.g., *"our second alternative hypothesis could not be tested because our sample size was too small."*).

Acknowledgments

This is an easy section-- just thank everyone who helped you substantially, but not everyone who did something minor. Don't thank the driver who took you to the airport as you departed for your study on Manus. On the other hand you might thank the boat operator who ferried you back and forth every day for a year to do your study on mangroves on Manus. Be sure to thank your donors—the people who funded the study! If you forget, they might not continue to support you. Try to keep this section short too-- if there are many people to thank, you can do so in a list without explaining what each person did. Once you have finished your paper you will probably get comments from reviewers that the editor gave your manuscript to, and you will be asked to incorporate these comments. It is good form to thank them, even if you don't know who they are and have to say, *"I thank three anonymous reviewers for comments on this paper."* Again, read journal articles to get an idea of how to write this section.

Literature Cited

Every written resource (article, book, thesis, map, etc.) mentioned in your paper needs to be recorded in detail in the literature cited section. Include only publications you mentioned in your text at least once. As we mentioned above, you use citations to make your paper shorter and to substantiate statements you make. So if the reader wants more details on your methods they will want to look at the paper you cited in your methods. If they are not convinced of a fact you report with a citation, they will want to go to the library to read that citation. Therefore, the information here provides at least enough information for the reader to locate the resources you used. You will give the author, year of publication, title of publication, journal, editor, publisher, etc.

Each reference is usually arranged in alphabetical order by the last name of the first author. With multiple references by the same author, they are usually arranged chronologically. Each journal seems to have its own specific format for this section and they are very rigid. Examine exactly how literature is cited in papers already published in the journal you are writing for and copy it exactly. Every comma, semi colon and period goes in a certain place. It is tedious work, but you have to do it properly or your manuscript could be rejected just for this reason! Some editors figure that if you cannot take the time to format your manuscript properly, then they will not take the time to consider it.

In your advancement as a scientist it is really important to take advantage of the literature cited sections of resources you read. If you read a paper on a topic that is similar to your interests or your area of specialization, then you should go through its literature cited section and you should read as many of the papers that author used as you can. This is a great way to find the literature that is relevant to your field. Becoming a good scientist means many hours in the library or online reading.

Appendices

This part of a paper is completely optional and many editors encourage writers to minimize the size and number of appendices. An appendix is just a place to add a big chunk of data, usually in the form of a table, that is important information but which is too extensive to include as a table in the results section. Appendices are not crucial information for the paper, but material you think is useful and should be published for others to use in the future. For example, on a biological survey we often report how many families, genera and species we found on the survey. But in the appendix we might actually list all of these; appendices like this are particularly useful for diverse taxa like plants, where the table would be way too long to be included in the paper itself. Every appendix should be referred to in the results section, just like tables and figures, but they appear at the very end of the paper.

Comments and tips about writing a scientific paper

We have discussed the basic components of a scientific paper, but you MUST read lots of scientific papers before you'll really be able to write a good paper. You will not acquire this critical skill in classes or training courses—reading is the only way! ***The more you read, the better you write.***

Paper sections usually appear in the order given above in the finalized manuscript, but that does not mean you actually have to write them in this sequence. For example, it is often easiest to leave the abstract until last. Usually the methods section is the easiest to write because it is simply a description of what you did, so it can be a good place to begin. If you've written a proposal before the project, it can be very useful to use pieces of it to get started on the introduction and discussion. Also, depending on the journal you might need to modify these sections. For example, some journals might want a summary at the end instead of an abstract. But these are minor differences. Learn to write a paper in this format and you will have no problems adapting this format to most journals.

Before you write your paper, think about the major points you want to come out of your paper. What do you want the reader to learn and remember if they only learn one thing from your paper. Design your writing around this major point. Most readers cannot digest a lot of separate points in one paper-- so make your paper drive home the most important point(s). If you try to put too much in one paper, you end up with an unfocused and diffuse paper that leaves the reader wondering what the point was.

Before writing your paper, identify your intended audience. If you are writing for other scientists, you will have a certain style. If you are targeting the general public, you will need a different style (and vocabulary). A good paper for scientists will fail if it is delivered to non-scientists and vice versa. Your manuscript will be written for a specific journal. First make sure you are totally familiar with that journal by reading many papers in it. Each journal has its own style, its own content and its own format. The closer your manuscript conforms to these, the better your chances of being published.

Writing is often THE most difficult part of a scientific project-- from inception to fund-raising, to living in tough field conditions, to analyzing the data.... most people find the hardest part is writing a good manuscript. This is the stage where you have to know your science and where you are subject to the most rigorous criticism. Out in the field on your own, no one is looking for flaws, but editors and reviewers

scrutinize your submitted manuscript for any flaw. They are professional flaw finders-- that is literally their job, and most do it very well.

Still, this is also THE MOST IMPORTANT AND GRATIFYING part of science. Once you have published a real scientific article, it is read by scientists around the world. We might be reading a paper by people from Bolivia while in the field in Herowana. Your papers go everywhere and have a wide audience-- they are an everlasting permanent contribution to science. Your name will be there in the library and read by students long after you have died. Take pride in writing-- you are doing something truly significant and lasting.

Because writing is difficult, plan to write. Include time to write in your schedule and stick to it. Set aside large blocks of time for writing and do not be distracted. There are always many easier and more fun things tempting you away from your writing. Do not allow yourself to be distracted! If you seem to get a block on your writing, do not stop. If you really hit a wall, switch to another part of the manuscript. If your work on the discussion is halted, work a bit on formatting your literature cited then go back to it.

Try to have the key reference material you need handy. Photocopiers are great inventions so you can have a handful of crucial papers right with you as you write. Consult them and re-read them as you go. But do not get caught up in the diversion of getting masses of reference material before you begin writing. Filing cabinets or hard drives full of unread papers will do you no good.

Turning out a good manuscript is an evolutionary process. You create something, from a paragraph to a section, review it and select the parts that are good and revise those that are not. You go over and over your manuscript, improving it each time. Do not expect to sit down and turn out a good manuscript in one draft. Get the main points in first, then go back and refine. With each pass you should look more carefully. By the end of the writing process you are looking at each sentence-- is your word choice perfect? Could a better verb work here?

Take advantage of colleagues and friends to review your paper. YOU know the subject matter so your paper makes sense. Give it to someone who does not know your project and see if it makes sense to them. If they say no, it needs fixing.

There are hundreds of writing tips, but this is not a style lesson. Just remember though, journals have limited space and they want everything short and clear. Avoid any redundancy. If you can say something in 8 words that you wrote in 10, cut it to 8. Usually a final draft is about half the size of the first draft. Everyone appreciates a short and concise paper. What sort of papers do you like to read?

The old school of scientific writing said to avoid the first person and the active voice. You wrote: "*the temperature was measured.*" But this is awkward and begs the question, “by whom?” Some mystical spirit floating in the forest? It is more interesting to the reader, shorter, and more accurate to write: "*I recorded temperature*." Most journals now encourage limited use of the first person and active voice. But keep it moderate. Don't make your methods sound like a letter home to Auntie Bess "*first I did this, then I did that, then we went here and we did this*..." Of course, the editor has the final word and if s/he says no first person, then you should write in the passive voice.

There are many more tips, but ***the most important is to read papers and practice writing them***. There is no secret formula, just lots of practice. Writing is a creative process that requires skill just like painting or sculpture. Yes it takes a lot of work, but truly anyone CAN do it if they practice. IF you master this skill, you will truly be among a rather small and "elite" subset of the human population. It will promote your career, earn you respect and status, and open the way to an extremely rewarding and fascinating career.

CHAPTER 15: How to Prepare an Oral Presentation or Poster

Introduction

To be a successful scientist you must communicate effectively. A good presentation cannot repair bad science, but good science can be damaged by poor presentation. You need to communicate your science to policy makers, to the public, to donors who fund your work, and particularly to other scientists. Modern science works through the peer review process. This requires that we communicate our science to our peers, i.e., other scientists, and that they also communicate their reviews back to you. If this communication process breaks down, good science might never reach publication or distribution to the broader community and other audiences.

Even if you have worked with your peers and communicated your science to the scientific community, you may still need to communicate with other audiences. This is particularly true in the field of conservation where you need to get your results across to practitioners who will then use your science to implement conservation measures. We cannot accomplish significant conservation completely on our own. Possibly a large landowner could manage his property well alone. But that conservation result would be much better if through communication many other landowners also managed their resources well.

Often the first step in formal communication with peers comes in the form of oral or poster presentations at professional meetings. Usually people attend these meetings to hear about the latest research, knowing that waiting for journal articles to come out could take 1-2 years longer. They go to get a "sneak preview" so they can keep up to date on the latest findings in their field. These meetings are an important time for us to test our ideas and results out on peers before trying to publish them in a permanent journal where we cannot go back and make corrections. You might get questions or comments from the audience that will alter your thinking, or show you how to explain yourself more clearly. Global scientific meetings can have thousands of people attending, all interested in the same things you are! They are an excellent way to network and meet possible collaborators.

Communication at these meetings is also as a means of "broadcasting" your science and findings. Peer-reviewed publication is essential, but if you really want people to embrace your results, you have to broadcast them at meetings. Often people will not read a full paper or really understand it; but they will listen to a 15 minute presentation and then understand your work. Always bear in mind that the ultimate goal of your research is to get a result communicated. Without communication, there is no point in even doing the research. Many people will tell you that just publishing alone, even in a top journal, is not enough. You need to get out there and actively promote your science.

Oral presentation is an excellent skill to develop in any profession. It is also a difficult skill to master. Not many people can claim to be great orators. But the ones who are can change history. We recommend you give serious effort to building your speaking skills. Join groups that encourage public speaking. Volunteer for opportunities to speak. But also, take advantage of opportunities to see people speak. Do not just listen to what they say, but pay attention to how

they say it. What about their speaking do you like? What is effective? What do they do that distracts you or loses your interest? You can learn as much about effective speaking from a poor speaker as you can from a good one! Many of the skills you need for scientific presentation are the same for any oral presentation. Someone can be a boring politician or scientist due to their shared poor speaking habits. Neither will get far in their career unless they correct those bad habits.

The best talks and posters are those in which the introduction clearly establishes "what and why", the transitions between slides or poster panels are smooth and logical, and the conclusions return to the ideas presented in the introduction.

Just like a scientific paper has a fairly standard structure you must follow, scientific presentations also follow a fairly proscribed format. This is a format that allows the most rapid and clear communication of your main results. It is important for scientific presentations to follow the standard general format. You have more flexibility in other forms of speeches or lectures. Here we discuss the scientific meeting presentation. Master this and you can likely move on to longer speeches and lectures with ease.

Oral Presentations

The standard oral presentation in the biological sciences is 15 minutes long. Generally you speak for 12 minutes and allow 3 minutes for questions after the talk. It might vary depending on the meeting and session, but the organizers will let you know when you register for a presentation (usually months before the meeting) how long you will have to speak. This time limit is not a recommendation. It is a hard and firm rule. You will not have 16 minutes on stage if they say 15. You can usually take a little less than the maximum, but going over the limit is unacceptable. Going over cuts time from the next speaker and is very rude.

Many meetings have concurrent sessions, with people talking in several different rooms. Someone might want to hear a talk in room A and then might want to switch and go over to room B to hear the next talk there. Everyone is talking on the same timetable to allow this. If speakers go over their time limit, it prevents the audience from moving to a different session in time to hear the beginning of the next talk there. You must plan and practice your talk so that you absolutely will NOT go over your allotted time. There will be an organizer there timing you, and they WILL cut you off which means you will not be able to finish your talk; the audience will not hear your conclusion.

The key to success in an oral presentation is practice, practice and more practice. We recommend practicing your final talk OUT LOUD at least 10-12 times. Only a very experienced and expert speaker can speak extemporaneously "off-the-cuff." You might see an effective speaker do this and think that is the key to success. But what you have not seen are the many times that speaker has worked to perfect their delivery before you have seen them. You will know when you are ready to speak about a topic without practicing beforehand. If you haven't spoken publicly at least dozens of times with a prepared talk, you are not ready to "wing-it." Giving a poorly-prepared presentation is an insult to your audience. It means you do not care enough about their time to prepare. You will never win over an audience you have insulted.

Many people fear public speaking. It makes almost everyone nervous. Although this is a problem, it is also a benefit. Because almost everyone is nervous about public speaking, almost everyone is very sympathetic and understanding to a speaker.

General Points

1. Giving a talk is very different from writing a manuscript or report. Manuscripts often have long sentences that are too hard to follow during an oral presentation; ***keep your sentences short.***

2. Although it is acceptable to have notes during your talk, ***do not read from notes*** like you are reading a manuscript. Practice, practice, and practice some more so you do not need to read from notes.
3. During a 12-minute talk, every word has to be carefully chosen. Thus, ***good organization is critical***. A common mistake is spending too much time on introduction and methods, with little time left for results and conclusions. In a short talk, do not spend more than ***2-3 minutes on your introduction and methods***.
4. Many experienced presenters claim that people can only remember ***three main points*** from a talk. What are your main points? Emphasize these points! Repeat these points in a summary at the end of your talk so your audience is left with them.
5. The main elements of a talk are the Introduction (which includes methods), the Body (Results and Discussion) and the Conclusion. Many people use these elements according to the following rule: ***Tell them what you are going to tell them, tell them, and then tell them what you told them.***
6. Have a good title slide. This should have the title, your name and what organization you are with.
7. Many people use a "Talk Outline" slide after the title to describe where they will take the audience (Figure 15.1). It lets the audience see what is coming so they can relax instead of guessing what's next.
8. Your slides should have headings. A heading lets the audience know where you are in your talk or reinforces the point you are making. Some presenters use section headings like: Introduction, Methods, Results, Discussion and Conclusions.
9. With good visual aids (see next section), you should be able to talk from your slides without reference to notes. In preparing your presentation, talk about the slide out loud to yourself while it is on your computer screen. If you get stuck or something doesn't sound right, modify the slide to make it clearer. Practice your talk so that the closing statements about one slide directly lead into the next one.

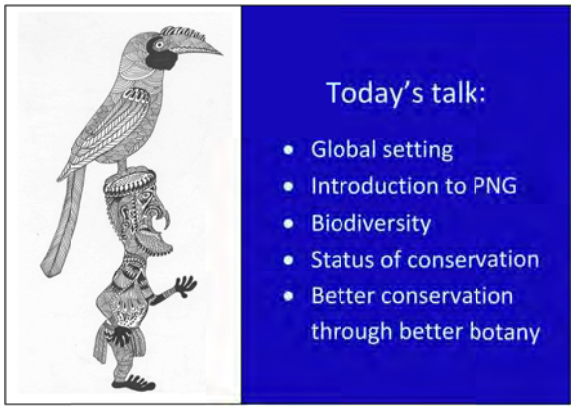


Figure 15.1. It can be helpful to give an outline of what you will be going through in your talk at the very beginning, right after the title. This is especially true for talks that do not follow the normal intro, methods, results and conclusions format. This way the audience knows what is coming and will not be wondering and so distracted, and they will also know when you are almost finished.

10. ***Practice and time your talk*** several times in front of a critical audience (e.g. your colleagues, classmates, etc). Get them to take notes on the parts that need improving. ***Remake slides that are confusing***; if you are not sure if something is clear, it probably needs to be redone! Be sure to finish within the time limit and be sure to leave 2 or 3 minutes for questions. Getting cut short by the session moderator at a meeting is extremely poor style – most meetings ***strictly enforce time limits***. Be sure to leave 2-3 minutes for questions.

Preparing your Slides

Almost all scientific meetings now use Powerpoint-- the computer software for presenting slides to an audience. The days of film transparencies are past. Overhead projectors are sometimes available, but usually only as a backup in case the PowerPoint projector system fails. More typically conferences will have backup Powerpoint projectors. The more likely problem

is that your copy of your Powerpoint presentation will become corrupted and not work. It is always a good idea to have more than one copy of your talk on different media-- like a CD and a flash drive.

1. ***Make simple slides*** **-** try to limit yourself to one idea per slide (two at the most). At a glance, your audience should know what a slide is attempting to communicate.
2. Provide a brief title for your slide; for a graph, this can be your conclusion from the graph (e.g., *Site A had more species than Site B*). A brief title of a few words provides an immediate focus for the audience (Figure 15.2).

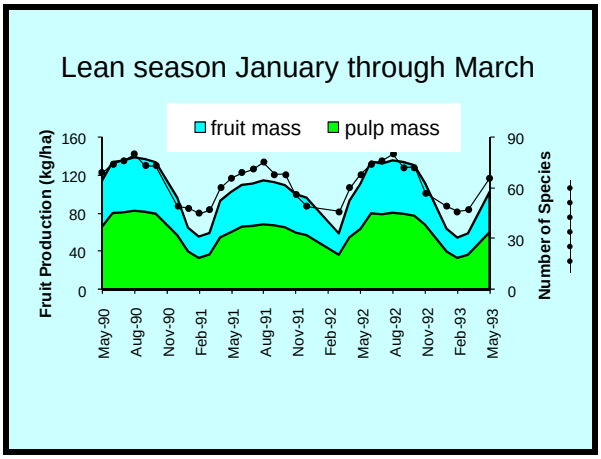


Figure 15.2. For this slide you would say: "Fruit mass is the entire weight of the fruit; pulp mass is the weight of the fruit minus the weight of the seed—or in other words, what the bird will actually digest. In this graph the blue and green areas show how much fruit and pulp the forest produced each month over a three year period. The dotted line shows the number of species that were in fruit during each month. You can see that less fruit and pulp was produced in each of the three years during January, February and March. And that fewer species were in fruit during these months also. It is clear that this forest has an annual fruiting lean season from January through March."

3. Some general rules to follow:
   a) Strive for ten or fewer lines of text per slide. Don't project a large paragraph!
   b) Strive for fewer than fifty words per slide. Simple phrases are OK, you don't need full sentences.
   c) Use plain fonts, e.g., Arial or Times New Roman. Avoid the temptation to use fancy fonts and stick to one font throughout the presentation unless there is a compelling reason to use a second font. Multiple fonts are distracting.
   d) Font sizes**:** headings 36 pt, text 24 pt (no smaller than 18 pt) with at least 1.5 spacing between lines. Remember that some audience members will be trying to read from the back of the auditorium and lines that are too closely spaced will blur together. Headings can be boldface. Again avoid the temptation to use lots of complicated formatting that WILL ***DISTRACT*** the audience.
   e) Use contrasting colours for text and background. Make sure your text stands out everywhere on the slide.
   f) Use upper and lower case letters; do not use all upper case. ALL CAPITALS IS THE EQUIVALENT OF SHOUTING IN PRINT AND IT IS HARDER TO READ.
4. If you exceed the above guidelines for the slide (i.e. you cannot cover it all in ten lines or 50 words), spread the points over two slides. You can use a cue that you are continuing the same thing. E.g., you can use the same heading with (continued) after it at the top of the slide to show that you are continuing the same point in more than one slide.
5. You do not need to follow the strict rules of English grammar and composition in Powerpoint slides. Avoid long, full sentences. Your audience will be too busy reading to hear you. Use brief, concise points. Bullet points are good.
6. Do not make slides from printed pages. Resist the lazy impulse to lift tables or figures straight from your manuscript or publication. They

almost always have to be remade for a slide, with larger fonts, thicker lines, fewer columns and rows. Never make a slide of raw information like a large table. Summarize with a few rows and columns. If there is content not directly relevant to your main message, omit it. It will only distract your audience and weaken your presentation.

7. Think carefully about your graphics and animation. Many slides are way too busy, with too many colours and fancy animation. Remember that people are there to hear your science, not to see how many tricks you know about making slides. ***Don't lose sight of the information content.*** Almost any animation in PowerPoint, like text flying in from all directions, distracts from your message.
8. Choose the colours carefully. Project your slides in advance to see how well the colours stand out from the back of a large room. Don't use jarring colour combinations or overuse very bright colours. Your audience might be in a dark room. A bright magenta slide can be uncomfortable to look at; so can a stark white one. Because 8% of males are red-green colour blind, avoid slides with both red and green where the viewer would need to differentiate them. For example, don't use red to indicate snakes and green to indicate frogs in the same bar graph.
9. Be consistent in the style of your slides. View your entire talk as a continuous flow, not as a series of disjointed ideas. Be consistent in background colour, font style and size, use of colour, bullets, labeling of axes, use of titles, and so on. You should be able to make a style that works for you and stick with it throughout the show. This will make it less distracting for your audience so they can concentrate on what you are trying to get across. Also, if you use the same style consistently in multiple presentations, it becomes easier to pull slides from different talks to make new talks. This will save you a lot of headache as you develop a library of presentations.
10. Have someone check your slides for misspelled words. Italicize scientific names. Make sure graphs can be understood quickly and be sure to explain them adequately. Walk your audience through the graph completely, including what you want them to see from it. If you talk in front of a complicated slide, without first explaining it, your point will be missed because the audience will be trying to figure out the visual slide. If you move on before your audience understands a graph, they might miss the entire point of the talk because they are still thinking about it, trying to figure it out.
11. Organize your presentation with one slide for every 30-60 seconds. You can get away with more slides if they are just pictures to set the scene (like three pictures to show the three species of pigeon you studied), that you will flip through quickly. But for text slides, make sure you give each one enough time for the audience to fully digest it. It is better to have one slide you talk about thoroughly than to click through many slides as you talk—your audience will not be able to read the slides at the same rate as you speak—they won't be able to read and listen equally well and become frustrated. Too many slides in a 12 minute talk can make it seem rushed; 30 or fewer works.
12. There is no excuse for bad slides. If you think you need to say "I'm sorry for the poor quality of this slide," then you should not use it. Exceptions would be things like photographs of hard-to-photograph study organisms.
13. The secret to a really good presentation is to practice, practice, and practice. When you get in front of an audience it will just flow from you if you have practiced enough. A talk full of "umm, uhhh, ahem, urrrr.... " pauses and stammers will flop.

On location, before your talk

1. If you are presenting at a new location, like a scientific meeting, be sure to preview your

talk in the room you will be presenting if possible. Make sure that your PowerPoint is loaded and runs. Usually there will be a person you are supposed to give your talk to and they will load it for you—you can ask to see it on screen to make sure it works). If you get in front of an audience and your slides do not project, you will have to give your talk without the benefit of slides. This is much harder to do, especially if you have graphs and data you need to show.

2. Get familiar with the room you will be presenting in well before your scheduled time. There is little worse than preparing for an intimate talk with 20 people and discovering you are in a huge lecture hall with 200 people. If you know what to expect you will present much better. Make sure you know how to operate any projectors, lights, pointers, and microphones before you are on stage speaking. Few things are as tedious as a speaker who wastes the first 2 minutes of a 12 minute talk figuring out how to get from the title slide to the next slide or how to use the microphone.
3. Bring water or throat lozenges if you will need them when you are speaking. Be prepared with whatever you might need-- a pointer or any other visual aid that will help.

On location, beginning your talk

1. Usually at a well-run program you will be introduced. A succinct "thank-you" after the introduction is enough, then get on with your talk. If you are not introduced, you can say who you are. It is good if your first slide gives the title of your talk and your name—then this can be used as your own introduction.
2. If there are co-authors or key collaborators their names should be on the first slide. Otherwise, acknowledgments go at the end; do not start with a long list of everyone who helped. Your audience wants to learn something, not hear a bunch of thank-yous.
3. Begin your talk decisively. Talks that begin with "Uh, well um, OK, let's see..." are weak and indicate you are unprepared. It insults your audience if you are not prepared. Likewise, don't put up a slide and say "now what was I going to say about this is…" – that is a waste of time. Just say it. Be authoritative and confident.
4. Throughout your talk look at your audience. Make eye contact briefly on and off with people in the audience. Do NOT stare at a corner in the back of the room. Are you talking to the corner? Do not look at the slide or your notes throughout the talk (glancing at them is fine). If the lights will be dimmed during your talk, it is a good idea to capture the attention of your audience by making eye contact with them before it gets dark to let them know you are talking to THEM. When they know this, they will listen better, feeling a connection with you (and afraid you will see them sleeping or bored!).

On location, during your talk

1. ***Be confident*** – you did the work and you should know it better than anyone in the audience. Try to be enthusiastic and vary your tone. A level monotone makes you sound like a robot and will put your audience to sleep!
2. Do not talk to the screen or to your notes. ***Talk to your audience***. (Although it's OK to occasionally refer to your notes). This is one of the main mistakes even experienced scientists make.
3. ***Do not fidget*** or jingle your keys or change in your pocket. Do not rock back and forth. Some movement on the stage is good. But repetitive movements become distracting and make you look like an animal in a cage.
4. It is best to ***speak loudly*** standing a little back from a microphone. It is good to practice with a microphone if you will be using one, before you are doing your talk. Learn not to make

explosive "P's" or sounds that become distorted or distracting over the microphone.

5. ***Do not talk too fast*** – this is especially true at meetings where some people speak English as a second language. The correct speed to talk often seems very, very slow to the presenter, but just right to the audience. Pause between slides. Remember if you talk too fast you can lose your audience, and if you continue to talk too fast, they might never catch up. You will have rattled away for 12 minutes and they will have learned nothing. This is not like reading; they cannot go back and re-listen to a passage they missed.
6. ***Avoid reading the text on slides word for word*** to your audience, unless you have a very important quote. The slide is a prompt for you. They can read the slide-- you should embellish and clarify.
7. ***Make sure that what you are saying is directly related to the slide,*** and go in the same order as things are shown on the slide so your audience can follow. There is little more confusing than a speaker saying one thing while the slide says something else. The audience must be able to connect the dots.
8. Jokes can be fine in small doses and if actually funny. If they are not funny or there are too many of them, your talk becomes a failure.
9. ***It is OK to pause*** while speaking to an audience. Pauses let your audience catch up with you and absorb your important points - they will not think you are dumb if there are short pauses, especially at key points. Remember that pauses always seem longer to the speaker than to the audience.
10. When using a laser pointer, keep it pointed on the area of interest, and then turn it off. It's very distracting when the speaker moves the pointer all around the slide. If you are nervous and your hand is shaking, you can move the pointer in a circle around what you are highlighting, or back and forth underneath it. But if you are so nervous the pointer jumps all over the place, this is distracting. If you have this problem, see if you can just use a solid pointer, like a meter stick. These don't show your shakes as much as a laser pointer!

On location, ending your talk

1. ***End your talk decisively***. Do not just stop and mutter something, leaving the audience to wonder if you are done.
2. ***Do not end with: "Are there any questions"*** -- the proper protocol calls for applause first. Rather, say something like "thank-you"; this clearly indicates you are done and cues the audience to applaud. After the applause the moderator will ask if there are any questions. Try to avoid lame endings like "Well, that's about all I have."
3. In handling questions, avoid combative answers. Part of the reason to present is to get feedback that might improve your work. Take constructive criticism as a positive thing.
4. Be sure to ask for clarification if you don't understand a question, and don't hesitate to say you do not know if you don't.

No one is born a good public speaker; public speaking is a craft that requires practice. The more public speaking you do, the better you will get. Therefore, take every opportunity you have to give presentations. On day, believe it or not, you will actually come to enjoy giving talks and getting feedback.

Poster Presentations

Preparing a poster is very different from preparing a talk. Although the audience has more time to absorb information from a poster than a quick slide, many people do not have the patience to spend more than a few minutes reading a poster. Additionally, poster sessions are often crowded and busy, conditions that can make close viewing difficult. Thus, it is just as critical in a poster as in an oral presentation to keep the text and graphics simple.

Some important points to remember:

1. Find out the size restrictions for the poster at the meeting you are attending and stay within these limits.
2. Do not pin pages of normal typed text or a manuscript to a bulletin board and call it a poster. As with a talk, ***extract the major points and present them in a simple, logical, and organized fashion***. These points (or "take home messages") should be obvious to the reader in just a couple of minutes. ***Your main points should even come across just by reading the title and abstract***. Realistically at a large meeting this is all most people will look at. If these capture their attention, they might read on through a bullet pointed introduction, methods, results and discussion and look at some graphs. Don't bother with a lengthy literature cited.
3. A poster should stand on its own and make sense even if you are not there to explain it. Usually in a poster session at a scientific meeting 90% of people read the abstract and move on, if they even read that much. You are there to answer questions for those who might have them. Someone might say "tell me the main points" rather than reading a complicated poster. Know what to say.
4. The most effective posters are those that convey the information in ***bullet-points with phrases***. Keep any sentences short and to the point.
5. ***Use large fonts***. Your goal is to make your poster easy to read; a general rule of thumb is that your poster should be able to be read from 1-2 m away. Suggested type sizes: use 84 pt font size for title, 42 pt for authors and addresses, 30 pt for section headings, 24 pt for text.
6. ***Mix text with good photographs or simple graphics*** that illustrate your points. This makes for a more interesting poster, especially if the graphics are in colour. Choose your colours and design your graphics carefully, just you do for a slide.
7. Many viewers will just look at the figures, especially if you have too much text to read. ***Each figure should have a large heading for the main point*** and a legend below it with more detail to further explain the figure (what you would have said aloud if it had been a talk). Remember, a casual viewer of your poster should be able to understand it without having to read the figure legends; the legends are strictly for those people who want to gain more detailed information. Tables should be simple and contain no extraneous material to distract the viewer from your main points. For ease of viewing, try to convert tables into figures.
8. It is a good idea to have a small picture of yourself in one corner of the poster. This allows people to pick you out from the crown surrounding the poster if they have a question. If you aren't there at the poster, it also enables them to find you and talk to you at the meeting if they are interested in what you had to say.

LITERATURE CITED

Allison, A. 1993. Biodiversity and conservation of the fishes, amphibians, and reptiles. Pages 157-225 *in* B. Beehler, editor. Papua New Guinea Conservation Needs Assessment. Department of Environment and Conservation, Waigani.

Allison, A., F. Kraus, and M. McShane. 2004. Patterns of Species Richness in the Papuan Region: A Preliminary Assessment Using Amphibians and Reptiles. Honolulu, Hawaii.

Balke, M. 2001. Biogeography and classification of New Guinean Colymbetini (Coleoptera : Dytiscidae : Colymbetinae). Invertebrate Taxonomy **15**:259-275.

Balke, M., I. Ribera, and A. P. Vogler. 2004. MtDNA phylogeny and biogeography of Copelatinae, a highly diverse group of tropical diving beetles (Dytiscidae). Molecular Phylogenetics And Evolution **32**:866-880.

Barnett, A. and J. Dutton. . 1995. Expedition Field Techniques: Small Mammals (excluding bats). Expedition Advisory Centre, London, England.

Basset, Y. 1999. Diversity and abundance of insect herbivores collected on Castanopsis acuminatissima (Fagaceae) in New Guinea: Relationships with leaf production and surrounding vegetation. European Journal Of Entomology **96**:381-391.

Basset, Y. and V. Novotny. 1999. Species richness of insect herbivore communities on Ficus in Papua New Guinea. Biological Journal Of The Linnean Society **67**:477-499.

Basset, Y., V. Novotny, S. E. Miller, G. D. Weiblen, O. Missa, and A. J. A. Stewart. 2004. Conservation and biological monitoring of tropical forests: the role of parataxonomists. Journal of Applied Ecology **41**:163-174.

Beehler, B. M. 1993. Biodiversity and conservation of the warm-blooded vertebrates of Papua New Guinea. Pages 77-155 *in* B. M. Beehler, editor. Papua New Guinea Conservation Needs Assessment. Biodiversity Support Program, Washington, D.C.

Beehler, B. M., T. K. Pratt, and D. A. Zimmerman. 1986. Birds of New Guinea. Princeton University Press, Princeton.

Beehler, B. M., J. B. Sengo, C. Filardi, and K. Merg. 1995. Documenting The Lowland Rain-Forest Avifauna In Papua-New-Guinea - Effects Of Patchy Distributions, Survey Effort And Methodology. Emu **95**:149-161.

Bibby, C. J., N. D. Burgess, and D. A. Hill. 1992. Bird census techniques. Academic Press, San Diego.

Blondel, J., C. Ferry, and B. Frochot. 1981. Point counts with unlimited distance. Studies in Avian Biology **6**:414-420.

Bonaccorso, F. J. 1998. Bats of Papua New Guinea. Conservation International, Washington, DC.

Bridson, D. and L. Forman. 1992. The herbarium handbook. revised edition. Royal Botanic Gardens, Kew.

Bub, H. 1991. Bird trapping and bird banding: a handbook for trapping methods all over the world. Cornell University Press, Ithaca, New York.

Buckland, S. T. 1987. On the variable circular plot method of estimating density. Biometrics **43**:363-?

Diamond, J. M. 1973. Distributional ecology of New Guinea birds. Science **179**:759-769.

Dudgeon, D. 1994. The Influence Of Riparian Vegetation On Macroinvertebrate Community Structure And Functional-Organization In 6 New-Guinea Streams. Hydrobiologia **294**:65-85.

Flannery, T. F. 1995. Mammals of New Guinea. Cornell University Press, Ithaca, N.Y.

Foley, D. H., J. H. Bryan, D. Yeates, and A. Saul. 1998. Evolution and systematics of Anopheles: Insights from a molecular phylogeny of Australasian mosquitoes. Molecular Phylogenetics And Evolution **9**:262-275.

Foster, M. S. and P. F. Cannell. 1990. Bird specimens and documentation: Critical data for a critical resource. Condor **92**:277-283.

Georges, A. and F. Guarino. 2005. Key to the Freshwater Turtles of the TransFly Institute for Applied Ecology, University of Canberra.

Georges, A., F. Guarino, and B. Bito. 2006. Freshwater turtles of the TransFly region of Papua New Guinea - notes on diversity, distribution, reproduction, harvest and trade. Wildlife Research **33**:373-384.

Gressitt, J. L. and R. W. Hornabrook. 1977. Handbook of common New Guinea beetles. Sheck Wah Tong Press, Hong Kong.

Harrington, H. D. and L. W. Durrell. 1957. How to identify plants. Swallow Press, Athens, Ohio.

Heyer, W. R., M. A. Donnelly, R. W. McDiarmid, L.-A. C. Hayek, and M. S. Foster, editors. 1994. Measuring and monitoring biological diversity: standard methods for amphibians. Smithsonian Institute Press, Washington, D.C.

Hii, J. L. K., T. Smith, A. Mai, S. Mellor, D. Lewis, N. Alexander, and M. P. Alpers. 1997. Spatial and temporal variation in abundance of Anopheles (Diptera: Culicidae) in a malaria endemic area in Papua New Guinea. Journal Of Medical Entomology **34**:193-205.

Hyndman, D. C. and J. I. Menzies. 1990. Rain forests of the Ok Tedi headwaters, New Guinea: an ecological analysis. Journal of Biogeography **17**:241-273.

Johns, R. J. 1978. A new approach to the construction of field keys for the identification of tropical trees. Australian Journal of Ecology **3**:403-409.

Johns, R. J. 1993. Biodiversity and conservation of the native flora of Papua New Guinea. Pages 15-75 *in* B. M. Beehler, editor. Papua New Guinea Conservation Needs Assessment. Department of Environment and Conservation, Waigani, Papua New Guinea.

Johnston, G. R. and S. J. Richards. 1993. Observations on the breeding biology of a microhylid frog (Genus Oreophryne) from New Guinea. Transactions of the Royal Society of South Australia **117**:105-107.

Karr, J. R. 1981a. Surveying birds in the tropics. Studies in Avian Biology **6**:548-553.

Karr, J. R. 1981b. Surveying birds with mist nets. Pages 62-67 *in* C. J. Ralph and J. M. Scott, editors. Estimating numbers of terrestrial birds. Cooper Ornithological Society, Los Angeles.

Keogh, J. S., R. Shine, and S. Donnellan. 1998. Phylogenetic relationships of terrestrial Australo-Papuan elapid snakes (subfamily hydrophiinae) based on cytochrome b and 16S rRNA sequences. Molecular Phylogenetics And Evolution **10**:67-81.

Kunz, T. H., editor. 1988. Ecological and Behavioral Methods for the Study of Bats. Smithsonian Institute Press, Washington DC.

Laurance, W. F. 1990. Comparative responses of five arboreal marsupials to tropical forest fragmentation. Journal of Mammalogy **71**:641-653.

Laurance, W. F. 1992. Abundance estimates of small mammals in Australian tropical rainforest:a comparison of four trapping methods. Wildlife Research **19**:651-655.

Lewinsohn, T. M., V. Novotny, and Y. Basset. 2005. Insects on plants: Diversity of herbivore assemblages revisited. Annual Review Of Ecology Evolution And Systematics **36**:597-620.

Ludwig, J. A. and J. F. Reynolds. 1988. Statistical Ecology. John Wiley & Sons, New York.

Mack, A. L. and P. West. 2005. Ten thousand tonnes of small animals: wildlife consumption in Papua New Guinea, a vital resource in need of management. The Australian National University, Canberra.

Mack, A. L. and D. D. Wright. 1996. Notes on the occurrence and feeding of birds at Crater Mountain Biological Research Station, Papua New Guinea. Emu **96**:89-101.

Malcolm, J. R. 1991. Comparative abundances of neotropical small mammals by trap height. Journal of Mammalogy **72**:188-192.

Malnate, E. V. and G. Underwood. 1988. Australasian natricine snakes of the genus Tropidonophis. Proceedings of the Academy of Natural Sciences **140**:59-201.

Mayr, E. 1963. Animal Species and Evolution. The Belknap Press, Cambridge, Massachsetts.

Mayr, E. and J. M. Diamond. 1976. Birds on islands in the sky: origin of the montane avifauna of northern Melanesia. Proceedings of the National Academy of Science **73**:1765-1769.

McCoy, M. 1980. Reptiles of the Solomon Islands, Wau.

Menzies, J. I. 1976. Handbook of Common New Guinea Frogs. Wau Ecology Institute.

Nagorsen, D. W. and R. L. Peterson. 1980. Mammal Collectors' Manual. Alger Press, Toronto, Canada.

Novotny, V., Y. Basset, S. E. Miller, R. L. Kitching, M. Laidlaw, P. Drozd, and L. Cizek. 2004. Local species richness of leaf-chewing insects feeding on woody plants from one hectare of a lowland rainforest. Conservation Biology **18**:227-237.

Novotny, V., A. R. Clarke, R. A. I. Drew, S. Balagawi, and B. Clifford. 2005. Host specialization and species richness of fruit flies (Diptera: Tephritidae)
in a New Guinea rain forest. Journal of Tropical Ecology **21**:67-77.

Oppel, S. 2006a. Comparison of two Odonata communities from a natural and a modified rainforest in Papua New Guinea. International Journal of Odonatology **9**:89-102.

Oppel, S. 2006b. Using distance sampling to quantify Odonata density in tropical rainforests. International Journal of Odonatology **9**:81-88.

Osborne, P. L. 1995. Biological and cultural diversity in Papua New Guinea: conservation, conflicts, constraints and compromise. Ambio **24**:231-237.

Paijmans, K. 1970. An analysis of four tropical rain forest sites in New Guinea. Journal of Ecology **58**:77-101.

Parker, T. H. 1991. On the use of tape recorders in avifaunal surveys. Auk **108**:443-444.

Parsons, M. 1991. Butterflies of the Bulolo-Wau Valley. Bishop Museum Press, Hawaii.

Pokon, R., V. Novotny, and G. A. Samuelson. 2005. Host specialization and species richness of root-feeding chrysomelid larvae (Chrysomelidae, Coleoptera) in a New Guinea rain forest. Journal of Tropical Ecology **21**:595-604.

Polhemus, J. T. and D. A. Polhemus. 2002. The Trepobatinae (Gerridae) of New Guinea and surrounding regions, with a review of the world fauna. Part 6. Phylogeny, biogeography, world checklist, bibliography and final taxonomic addenda. Insect Systematics & Evolution **33**:253-290.

Price, D. S. 1994. Observations on the Ecology and vocalization of Xenorhina oxycephala (Schlegel), (Anura: Microhylidae) of New Guinea. Science in New Guinea **20**:141-146.

Remsen, J. V. 1995. The importance of continued collecting of bird specimens to ornithology and bird conservation. Bird Conservation International **5**:145-180.

Salamon, M. and b. Klettenheimer. 1994. A new technique for marking and later recognizing small mammals in the field. Journal of Zoology, (London) **233**:314-317.

Salas, L. A. and S. S. Stephens. 2004. Capture and immobilisation of cuscuses and ringtail possums in Papua New Guinea. Wildlife Reseach **31**:101-107.

Saulei, S. M. 1990. Forest research and development in papua new guinea. Ambio **19**:379-382.

Smith, R. E. W. and T. G. Morris. 1992. The impacts of changing geochemistry on the fish assemblages of the Lower Ok Tedi and Middle Fly River, Papua New Guinea. Science of the Total Environment 125:321?344. Science of the Total Environment **125**:321-344.

Tyler, M. J. 1968. Papuan hylid frogs of the genus *Hyla.* Zoologisches Verhandelingen Leiden **96**:1-203.

van Valkenburg, J. C. H. and P. Ketner. 1994. Vegetation changes following human disturbance of mid-montane forest in the Wau area, Papua New Guinea. Journal of Tropical Ecology **10**:41-54.

Womersley, J. S. 1976. Plant collecting for anthropologists, geographers and ecologists in Papua New Guinea. PNG Government Printing Office, Port Moresby.

Yule, C. M. and R. G. Pearson. 1996. Aseasonality of benthic invertebrates in a tropical stream on Bougainville island, Papua New Guinea. Archiv Fur Hydrobiologie **137**:95-117.

Zweifel, R. G. 1972. A Review of the Frog Genus Lechriodus (Leptodactylidae) of New Guinea and Australia. American Museum Novitates **2507**:1-44.

APPENDIX 1. Data Sheets

Data sheets are essential for organizing your data. Proper use of data sheets will make your field work easier, they will help you avoid making mistakes, and they will simplify and speed your data analysis. In this Appendix we present some sample data sheets. You can photocopy these and use them for your own field work. You might find that these particular sheets are not ideal for your particular project, and if so you should design your own data sheets with headings for the information you need to collect for your project. If you plan ahead you can print out one, like these, and photocopy it as many times as you need to before you go in the field. Alternatively, you can draw your sheets up in the field with a ruler on paper or in a field book. ***Use a pencil or waterproof ink!!! It WILL rain!*** And remember to make a copy of your data when you get back to base—if you are staying in town you can photocopy it, if you are bush, copy it all by hand on fresh sheets. Keep the copy in a different location than the original.

For each datasheet we will give brief notes so you know what to record.

Expenditures: Expense datasheet

NAME: Record your name here.
PROJECT: Record what project you are conducting/spending the money for. If it is a combination of several projects just leave this blank.
DATE: Date the item was purchased—be sure to use the format 2Mar10, *NOT* 2/3/10. The latter could be either 2nd of March or 3rd of February.
WHERE: Record where you were when you made the purchase—this can be useful information if some purchases were made in town (e.g., Goroka) and others were made out in a village (e.g., Herowana) or camp (Survey Site 1).
TO WHOM: Record the name of the person or the store that you gave the payment to.
FOR WHAT: Record what the purchase was for (e.g., batteries and rope, or carrying cargo Haia to camp, or market food).
KINA: Write the amount of the purchase.
RECT?: Record whether you have a receipt for this purchase or not (Y or N). You should have receipts for all purchases; keep them in a safe place and make photocopies of them when you get back to an office. Some donors require receipts and they will not allow you to use the grant for purchases without receipts—which means you pay for it yourself! If you are in the field or at a market and the seller does not give receipts, you can fill one out BUT make sure to get that person to sign the receipt or put their thumbprint on it.

NAME_____

PROJECT_____

DATE	WHERE	TO WHOM	FOR WHAT	KINA	RECT?

Plants: Tree plot data sheet

At the top of the sheet fill in the date, the location of the plot, and the names of all of the observers collecting the data on this datasheet (so people will know who to come to with questions).

TREE#: Every tree on the plot has a unique number recorded here

DBH: Record the diameter at breast height here.

HT: Record your estimate of the tree height here.

PLOT #: Record which sub-plot each tree is in

X: If you are mapping plant positions, record the x-co-ordinate here.

Y: If you are mapping plant positions, record the y-co-ordinate here.

LOCAL NAME: If you have someone with you who knows the local plant names, record the tok ples name here.

ID: If you know it, this can the genus/species, or could just be a family name if that is all you know. Or it could be a catalogue number that refers to a collection you think is the same species, or it could be a morpho-species number or name (a name you have given for plants that all share the same features and you think are the same species—usually something like "*Syzygium* A", or "hairy red fig").

VOC: If the voucher number is just the tree number you can put a check in this box to show you have collected it. If you are giving the plant a different voucher number other than the tree # you record that here (e.g., if you record and describe the specimen in your catalogue you would write down the catalogue number here).

HABIT: Record if it is a tree, liana, if buttressed, etc. here.

SAP: Record if the slash shows latex and describe it (color, texture, etc.). If there is no sap, write "none."

BARK: Describe the color and texture of the bark; does it have lenticles? Fissures?

UNDERBARK: Describe the color and texture of the under-bark.

WOOD: Describe the color and texture of the wood.

OTHER: Put any additional notes here, or on the bottom of the page with reference to the unique TREE #.

DATE:_____LOCATION:_____OBSERVERS:_____

TREE #	DBH (cm)	HT (m)	PLOT #	X	Y	LOCAL NAME	ID	VOC	HABIT	SAP	BARK	UNDER -BARK	WOOD	OTHER

NOTES:

Birds: Bird mist-netting data sheet

REC #: Every capture should have a sequential, unique record number. This enables you to keep track of each individual capture. You use this rec# as a reference for additional notes at the bottom of the page or in other places.

TAXA: This is where you write the genus/species for the bird netted.

DATE: Date of each capture; use 3 letter abbreviation for month, NOT a number, e.g., 8Mar10

HOUR: Record what time the bird was captured; use a 24 hour clock (e.g., 1800 hrs for 6 PM or 0600 hrs for 6 AM).

NET: You should number all your nets and record the habitat for each net (e.g., in a gap, over a stream, etc) and the precise location of each net on a separate sheet. In this column you record the number for the net you captured that particular bird in. You can later use these data to calculate how far recaptured birds have moved.

BAND (R): Record the band number if banding birds (banding is not essential for surveys and probably is better undertaken at sites where on-going monitoring will occur). The R is written before the band number if the bird is a Recapture of a previously banded bird (you did not put a new band on the bird).

SEX/AGE: Many species can be sexed or aged by plumage characteristics. If so, record the sex and/or age. If unknown put a question mark.

MASS (g): Above the horizontal line write the weight of the bird and bag, put a minus sign, and then write the weight of the bag. Below the horizontal line write the difference between the two (= the weight of the bird). This way you can later see if you made a mistake in the field with your subtraction. If you just write the difference, you have no way of double checking if your subtraction was correct or not and EVERYONE makes subtraction mistakes.

WING (mm): The wing chord measurement in millimeters.

BILL (mm): The bill measurement in millimeters. You should specify at the top of each sheet if bill measurements are the culmen or the exposed culmen.

BP (0 +): Put a 0 if there is no Brood Patch and a + if there is a brood patch.

FAT (0-4): Fat is scored on a scale of 0-4 with 0 being no fat; this will be demonstrated in the field.

BODY (0-4): Body molt (contour feathers) is scored on a scale of 0-4 with 0 being no molt.

PRIMARY LR I-X: Record molt of primary feathers (outer wing) for the **L**eft and **R**ight wing, record which primaries are in molt using Roman numerals and how developed the molting primary is P= pin feather, 1/4, 1/2, 3/4, F = full length but very new. For example, L-IV-1/2 means left wing fourth primary is half way grown in.

2nd #: Record the number of secondary feathers (inner wing) in molt on each wing (L or R), for example, L-3, R-2.

TAIL #: Record the number of tail feathers in molt.

OBS: The initials of the observer-- that person actually scoring and measuring; you might take turns with someone while using the same datasheet; this is why it needs to be recorded every time. Some observers are very experienced and you will probably not doubt their records; others could be new and if there is data that seems off you might not accept it.

COMMENTS: Any additional notes. If more room is needed, write the REC # with the comments for that individual on the bottom or margins of the page.

REC #	TAXA	DATE	HOUR	NET	BAND (R)	SEX AGE	MASS (g)	WING (mm)	BILL (mm)	BP 0+	FAT 0-4	BODY 0-4	PRIMARY LR I-X	2nd #	TAIL #	OBS	COMMENTS

ADDITONAL NOTES:

Mammals: Mammal trapping or netting data sheet

REC: Every capture should have a sequential, unique record number so you can keep track of individual captures. Use this rec# as a reference for additional notes at the bottom of the page or in other places.

DATE/TIME: Date of each capture; use 3 letter abbreviation for month, NOT a number, e.g., 8Mar10. For bats, record the time it was captured; use a 24 hour clock (e.g., 1800 hrs for 6 PM or 0600 hrs for 6 AM). For traps record "day" or "night" to indicate when the animal was caught.

TRAP/NET#: Record the specific trap or net number. These numbers should be unique within each date. I.e., you will not have two traps numbered 23 on the same night. In your field book, to go with these datasheets, you will have a map of all of your traps and nets with information for each trap or net number on its placement, site location and description, and the dates it was run. You will also record the total trapping or netting effort for each day/night (how many of each kind of traps you ran, how many net-meter-hours you ran with time you opened the nets and time you closed them). Do not forget to do this for every day of your study!

TAXA: Record your field id here (what you think the genus/species is). If you do not know write a question mark and collect the animal. Write collected here and make sure you refer to the capture REC# in your catalogue so you can cross reference to this data.

SEX/AGE: If you can determine it, record the individual's sex (M or F) and age (A for adult, SA for sub-adult or J for juvenile). Otherwise put a question mark.

MARK (Recap): Record any mark you have given the animal—this could be permanent ear tag numbers (e.g., "L-56/R-57"), a PIT tag number (e.g., "PIT23456"), colored ear beads (L-rdbl/R-blgr), a band number (for a bat e.g., B256), or it could be a temporary mark (e.g., "R hip fur" if you clipped the fur on the right hip, or "L wing punch" if you made a punch in the left wing). If the animal is a recapture and already has a mark, record "Recap" and write down its mark.

MASS: Above the horizontal line write the weight of the mammal and bag, put a minus sign, and then write the weight of the bag. Below the horizontal line write the difference between the two (= the weight of the mammal). This way you can later see if you made a mistake in the field with your subtraction.

HB: Record head-body length.

TV: Record tail length; if it is a bat with no tail record no tail. If the tail has been damaged and so is not full length, make a note of that.

EAR: Record ear length.

HF: Record the hind-foot length. Note in the column heading if this is with or without claws, or give both (e.g., "18w, 16w/o").

FA: Record the forearm length for bat captures.

TR: Record the tragus length for bat captures.

PERF/TESTES: If it is a female record if the vagina is perforate or imperforate (perf or imperf); if it is a male record whether the testes are small, medium or large.

PREG/LACT: If it is a female feel for a fetus (a hard round ball) and estimate whether the animal is in 2nd or 3rd trimester pregnancy; also record whether she is lactating or not, and if so, whether the mammary glands are enlarged or not and if the milk is copious or just a bit.

MAM FORM: Record the mammary formula for the capture (e.g., 2+2=8).

NIPS: Record nipple appearance, e.g., large/pink or tiny/white.

OBS: The initials of the observer-- that person actually scoring and measuring; you might take turns with someone while using the same datasheet and so it needs to be recorded every time. Some observers are very experienced and some are not; you will trust the data of the former more.

COMMENTS: Any additional notes. If more room is needed, write the REC # with the comments for that individual on the bottom or margins of the page.

REC #	DATE/ TIME	TRAP NET#	TAXA	SEX/ AGE	MARK (Recap)	MASS (g)	HB (mm)	TV (mm)	EAR (mm)	HF (mm)	FA (mm)	TR (mm)	PERF/ TESTES	PREG/ LACT	MAM FORM	NIPS	OBS	COMMENTS
						_____												
						_____												
						_____												
						_____												
						_____												
						_____												
						_____												
						_____												
						_____												
						_____												
						_____												

ADDITONAL NOTES:

Herpetofauna: Datasheets for 5 X 5 meter herpetofauna leaf litter plots and for visual encounter transects

PLOT #: Sequentially number the plots and transects you survey. You should use this number if you tag the plot in the field.
OBSERVERS: Record the names of the people working on the plot or doing the transect.
LOCATION: Record the survey location in detail so that each data sheet can stand alone.
DATE: Fill in the date the plot or transect was surveyed; use a 3-letter abbreviation for the month (e.g., 6Mar10).
STARTING TIME: Record the time you begin working the plot or walking the transect. Use the 24 hour clock (e.g., 1300h for 1:00 PM)
ENDING TIME: Record the time you finish working the plot or walking the transect. Use the 24 hour clock (e.g., 1300h for 1:00 PM)
CLOUD: Estimate the percentage cloud cover during the census.
RAIN: Record if it is raining during the census and how hard it is raining.
TEMPERATURE: Measure the air temperature just above the litter in the center of the plot, or the air temperature for transects.
MOON: Describe what phase the moon was in.
TREES: Record the number of trees ≥ 10 cm dbh in the plot.
LOGS: Record if there are any fallen trees/stems in the plot and how large they are.
STONES: Record if there are any large stones in the plot and their size.
STEEPNESS: Record if the plot is on level ground and if not, roughly how steep the terrain is (angle of slope).
SHADE: Estimate the shadiness of the plot in terms of percentage canopy cover (100% cover means no open sky visible above the plot, 0% means completely open above the plot)
WETNESS: Describe how wet the litter is.
LEAF LITTER POINTS 1-4: Measure the depth of the litter at four randomly chosen points in the plot.
HABITAT DESCRIPTION: Describe the habitat surrounding the plot.

REC#: Every capture should have a sequential, unique record number. This enables you to keep track of each individual capture. You use this rec# as a reference for additional notes at the bottom of the page or in other places.
TAXA: Record genus and species names. Put a question mark if you do not know it and collect the animal for later id. Write collected here and make sure you refer to the capture REC# in your catalogue so you can cross reference to this data.
SVL: Record snout-vent length in mm.
MASS: Record the weight of the animal in grams.
LOCATION: Record the location within the plot or along the transect.
OBS: Initials of the person taking the animal's measurements and identifications for each record. Some observers are very experienced and you will probably not doubt their records; others could be new and if there is data that seems off you might not accept it.
NOTES: Any additional notes. Write the REC # with the comments for that individual on the bottom or margins of the page.

5 X 5 METER LEAF LITTER PLOT #_____

OBSERVERS_____

LOCATION_____

DATE_____ STARTING TIME_____ENDING TIME_____

CLOUD_____ RAIN_____ TEMPERATURE_____ MOON_____

TREES_____ LOGS_____ STONES_____

STEEPNESS_____SHADE_____ WETNESS_____

LEAF LITTER (mm): Pt.1_____ Pt.2_____ Pt.3_____ Pt.4_____

HABITAT DESCRIPTION_____

_____

_____

REC.	TAXA	SVL (mm)	MASS (g)	LOCATION	OBS.

NOTES:

NIGHT TRANSECT #_____

OBSERVERS_____

LOCATION_____

DATE_____ STARTING TIME_____ENDING TIME_____

CLOUD_____ RAIN_____ TEMPERATURE_____ MOON_____

HABITAT DESCRIPTION_____

_____

_____

_____

REC.	TAXA	SVL (mm)	MASS (g)	LOCATION	OBS.

NOTES:

APPENDIX 2. Random Number Table

We generated these random numbers from *www.stattrek.com*; there are several random number generators online and you can easily find them with a google search.

To use this printed table randomly select a page from the table. Then close your eyes and put your pencil down on the page. This is your random digit. If you need a number between 0 and 99 you will do this twice to get your two digits (the first digit could be zero), if you need a number between 0 and 999 you will do it 3 times, etc. If you need a number between 0 and 360 (like a compass bearing) you will do it until you get a 0, 1, 2, or 3 for your first digit, then the second two digits can be anything between 0 and 9.

Ideally if you need a lot of random numbers you should go online and generate new random number tables for every few numbers you need so that you won't introduce bias (e.g., you might usually put your pencil down in the middle of the table and so commonly get numbers in the same general area, not actually using much of the table).

We included this table because for some of our courses we will be in the field, and so we will need to generate our random numbers without the use of a computer. However, if you are in town, or know what random numbers you will need before you go bush, you can go to a website like the one above and it will easily generate the numbers for you. For example, say you needed to generate 10 random compass bearings. You would go online, tell it you need 10 random numbers between 0 and 360, that it can give duplicate numbers (this is like throwing the croc back in for re-sampling), and it will give you your random bearings to use.

Random Number Table: Page 1

34733 73444 10425 99484 79190 40073 57422 58491 55286 64899 36060 22579 36464 94807
19779 18306 49282 56354 61695 45673 93739 22983 08693 78121 43278 47809 87330 42209
51014 77717 97607 37937 63831 39264 12965 65304 08288 05893 59963 24310 57827 30719
38601 88398 39005 60627 48877 84126 78381 22174 64236 11493 96280 88803 11234 43941
72376 13629 89871 08029 53554 43537 00148 03757 66372 05084 15506 31124 10829 71713
89062 90130 86926 96539 41141 54218 68104 26447 51418 49945 80921 87994 93334 77312
25378 54623 40332 09761 74917 79449 18970 73849 82653 09356 02689 69576 95471 44346
44605 96943 13370 37532 91603 29392 89466 35801 70240 20038 70645 92266 80517 15765
83462 27256 95875 16574 27919 20442 42873 75581 04016 18711 21510 39669 85194 75176
31787 35396 98011 10165 47146 62763 42469 03352 94143 95212 92007 01620 72781 85858
99743 31528 83058 81585 12561 93075 98416 82394 30460 86262 45414 41400 06557 84530
24051 05488 87735 14438 34328 01216 00552 75985 76244 28583 45009 69172 23242 61031
21106 67440 01880 25119 02284 97348 85598 20847 15102 58895 27515 48214 59559 52082
74513 07220 09097 50350 53150 71308 16833 80258 36869 67036 29651 41805 78785 94403
74108 34992 25783 26851 23647 33260 04420 90939 04825 63168 14697 86667 17642 24715
30055 14033 62099 17901 77053 46482 38196 16170 55691 37128 19374 46077 65967 32855
32192 07625 81326 33664 76649 00811 28324 92671 26187 99080 06961 56759 33923 28987
17238 52486 46741 90535 32596 79853 91198 83721 06152 12302 40737 81989 84789 02948
21915 11897 68508 98675 34733 73444 10425 99484 79190 40073 57422 58491 55286 64899
36060 22579 36464 94807 19779 18306 49282 56354 61695 45673 93739 22983 08693 78121
43278 47809 87330 42209 51014 77717 97607 37937 63831 39264 12965 65304 08288 05893
59963 24310 57827 30719 38601 88398 39005 60627 48877 84126 78381 22174 64236 11493
96280 88803 11234 43941 72376 13629 89871 08029 53554 43537 00148 03757 66372 05084
15506 31124 10829 71713 89062 90130 86926 96539 41141 54218 68104 26447 51418 49945
80921 87994 93334 77312 25378 54623 40332 09761 74917 79449 18970 73849 82653 09356
02689 69576 95471 44346 44605 96943 13370 37532 91603 29392 89466 35801 70240 20038
70645 92266 80517 15765 83462 27256 95875 16574 27919 20442 42873 75581 04016 18711
21510 39669 85194 75176 31787 35396 98011 10165 47146 62763 42469 03352 94143 95212
92007 01620 72781 85858 99743 31528 83058 81585 12561 93075 98416 82394 30460 86262
45414 41400 06557 84530 24051 05488 87735 14438 34328 01216 00552 75985 76244 28583
45009 69172 23242 61031 21106 67440 01880 25119 02284 97348 85598 20847 15102 58895
27515 48214 59559 52082 74513 07220 09097 50350 53150 71308 16833 80258 36869 67036
29651 41805 78785 94403 74108 34992 25783 26851 23647 33260 04420 90939 04825 63168
14697 86667 17642 24715 30055 14033 62099 17901 77053 46482 38196 16170 55691 37128
19374 46077 65967 32855 32192 07625 81326 33664 76649 00811 28324 92671 26187 99080
06961 56759 33923 28987 17238 52486 46741 90535 32596 79853 91198 83721 06152 12302
40737 81989 84789 02948 21915 11897 68508 98675 34733 73444 10425 99484 79190 40073
57422 58491 55286 64899 36060 22579 36464 94807 19779 18306 49282 56354 61695 45673
93739 22983 08693 78121 43278 47809 87330 42209 51014 77717 97607 37937 63831 39264
12965 65304 08288 05893 59963 24310 57827 30719 38601 88398 39005 60627 48877 84126
78381 22174 64236 11493 96280 88803 11234 43941 72376 13629 89871 08029 53554 43537
00148 03757 66372 05084 15506 31124 10829 71713 89062 90130 86926 96539 41141 54218
68104 26447 51418 49945 80921 87994 93334 77312 25378 54623 40332 09761 74917 79449
18970 73849 82653 09356 02689 69576 95471 44346 44605 96943 13370 37532 91603 29392
89466 35801 70240 20038 70645 92266 80517 15765 83462 27256 95875 16574 27919 20442

Random Number Table: Page 2

42469 03352 94143 95212 92007 01620 72781 85858 99743 31528 83058 81585 12561 93075
98416 82394 30460 86262 45414 41400 06557 84530 24051 05488 87735 14438 34328 01216
00552 75985 76244 28583 45009 69172 23242 61031 21106 67440 01880 25119 02284 97348
85598 20847 15102 58895 27515 48214 59559 52082 74513 07220 09097 50350 53150 71308
16833 80258 36869 67036 29651 41805 78785 94403 74108 34992 25783 26851 23647 33260
04420 90939 04825 63168 14697 86667 17642 24715 30055 14033 62099 17901 77053 46482
38196 16170 55691 37128 19374 46077 65967 32855 32192 07625 81326 33664 76649 00811
28324 92671 26187 99080 06961 56759 33923 28987 17238 52486 46741 90535 32596 79853
91198 83721 06152 12302 40737 81989 84789 02948 21915 11897 68508 98675 34733 73444
10425 99484 79190 40073 57422 58491 55286 64899 36060 22579 36464 94807 19779 18306
49282 56354 61695 45673 93739 22983 08693 78121 43278 47809 87330 42209 51014 77717
97607 37937 63831 39264 12965 65304 08288 05893 59963 24310 57827 30719 38601 88398
39005 60627 48877 84126 78381 22174 64236 11493 96280 88803 11234 43941 72376 13629
89871 08029 53554 43537 00148 03757 66372 05084 15506 31124 10829 71713 89062 90130
86926 96539 41141 54218 68104 26447 51418 49945 80921 87994 93334 77312 25378 54623
40332 09761 74917 79449 18970 73849 82653 09356 02689 69576 95471 44346 44605 96943
13370 37532 91603 29392 89466 35801 70240 20038 70645 92266 80517 15765 83462 27256
95875 16574 27919 20442 42873 75581 04016 18711 21510 39669 85194 75176 31787 35396
98011 10165 47146 62763 42469 03352 94143 95212 92007 01620 72781 85858 99743 31528
83058 81585 12561 93075 98416 82394 30460 86262 45414 41400 06557 84530 24051 05488
87735 14438 34328 01216 00552 75985 76244 28583 45009 69172 23242 61031 21106 67440
01880 25119 02284 97348 85598 20847 15102 58895 27515 48214 59559 52082 74513 07220
09097 50350 53150 71308 16833 80258 36869 67036 29651 41805 78785 94403 74108 34992
25783 26851 23647 33260 04420 90939 04825 63168 14697 86667 17642 24715 30055 14033
62099 17901 77053 46482 38196 16170 55691 37128 19374 46077 65967 32855 32192 07625
81326 33664 76649 00811 28324 92671 70456 98891 40144 16386 34544 80070 70052 26663
30272 92887 31599 42021 57639 37344 98228 15577 16645 13441 23054 67657 80733 94619
52962 77933 76461 07437 14509 19850 03828 51894 81138 66847 36276 01432 05964 45485
00364 09168 35872 29204 96092 21986 70861 71120 23459 39885 64048 18118 55907 15982
62316 96755 46553 97160 18782 07032 42280 09977 53771 22390 43089 54434 46957 69388
02096 30531 45226 48026 66184 11709 01691 58302 61911 24527 36681 73661 89278 68984
29867 20659 21727 18522 28136 99296 12373 26258 58043 09573 08100 39076 19591 24931
08909 56975 12777 71929 67916 33072 11045 50566 32004 14250 40953 60843 27731 27067
02500 02760 55098 71525 95687 49757 87547 47621 93955 28395 51635 28799 23863 12114
47362 41617 85410 54030 74729 86074 78597 01028 33735 35613 76865 79665 97823 43349
06773 63384 93551 56166 68320 05300 20918 00623 61507 52298 53366 50162 59775 30935
17454 31340 89683 41212 13182 44158 51230 56571 40549 88615 44417 03569 72997 64711
42685 82206 63643 45889 72593 92483 59371 58707 34140 07841 60180 03164 27327 54839
19186 52703 25595 33476 83274 60439 55503 43753 79001 73256 17050 59111 06368 17713
10236 32667 38817 67252 08505 11305 29463 48430 38412 95023 25190 61248 99960 36940
25999 60452 21335 38685 39753 36548 46162 17322 03841 17726 76069 01041 99568 30544
37616 42957 26935 75001 04245 89955 59384 24540 29071 68592 23472 32276 58979 78869
19199 45093 20526 94228 46566 89551 87155 41225 05573 39089 11981 19863 69660 20267
41889 30140 65388 59643 03436 45498 92755 77542 70065 92496 25203 53638 94891 71133
89291 34817 24799 81410 85019 47634 86346 96768 12386 92091 52975 70324 71392 68188

Random Number Table: Page 3

77801 22404 35480 49366 07709 32680 31208 62184 69256 74597 58575 06641 35885 21595
91023 56179 60711 00232 55111 63915 90619 83951 50839 76733 25608 25867 78206 94632
18795 72865 10654 70729 17063 51502 01300 51907 73529 61779 97027 64724 08518 77137
97836 09181 01704 24135 56843 85278 99973 02773 20931 66456 56438 13049 16658 79274
91428 28408 44025 23731 84614 75406 76474 73269 82883 54043 67120 81005 12790 64320
62847 93823 74338 79678 63656 11722 67524 26676 22663 87819 65792 05313 86751 68997
95700 15590 82478 81814 57247 57507 09845 26272 50434 04504 42294 02368 48702 83142
06382 83546 78610 66861 02109 96364 40157 08777 29476 40821 33344 55775 88482 90360
31612 34412 52570 98096 61520 18131 48298 10913 23067 60047 75665 55370 16254 07045
08113 04909 14522 85682 72201 86087 44430 95959 67929 98905 05977 11318 95296 43362
99164 58316 27744 19458 97432 36953 18390 00636 27340 47230 14118 13454 88887 62588
14927 57911 82074 09586 73933 07450 80342 88223 38021 15186 10250 98500 33748 28003
71797 13858 61115 72460 64983 87414 93564 21999 63252 66052 84210 03177 93159 49770
79937 15995 54707 91687 80746 60452 21335 38685 39753 36548 46162 17322 03841 17726
76069 01041 99568 30544 37616 42957 26935 75001 04245 89955 59384 24540 29071 68592
23472 32276 58979 78869 19199 45093 20526 94228 46566 89551 87155 41225 05573 39089
11981 19863 69660 20267 41889 30140 65388 59643 03436 45498 92755 77542 70065 92496
25203 53638 94891 71133 89291 34817 24799 81410 85019 47634 86346 96768 12386 92091
52975 70324 71392 68188 77801 22404 35480 49366 07709 32680 31208 62184 69256 74597
58575 06641 35885 21595 91023 56179 60711 00232 55111 63915 90619 83951 50839 76733
25608 25867 78206 94632 18795 72865 10654 70729 17063 51502 01300 51907 73529 61779
97027 64724 08518 77137 97836 09181 01704 24135 56843 85278 99973 02773 20931 66456
56438 13049 16658 79274 91428 28408 44025 23731 84614 75406 76474 73269 82883 54043
67120 81005 12790 64320 62847 93823 74338 79678 63656 11722 67524 26676 22663 87819
65792 05313 86751 68997 95700 15590 82478 81814 57247 57507 09845 26272 50434 04504
42294 02368 48702 83142 06382 83546 78610 66861 02109 96364 40157 08777 29476 40821
33344 55775 88482 90360 31612 34412 52570 98096 61520 18131 48298 10913 23067 60047
75665 55370 16254 07045 08113 04909 14522 85682 72201 86087 44430 95959 67929 98905
05977 11318 95296 43362 99164 58316 27744 19458 97432 36953 18390 00636 27340 47230
14118 13454 88887 62588 14927 57911 82074 09586 73933 07450 80342 88223 38021 15186
10250 98500 33748 28003 71797 13858 61115 72460 64983 87414 93564 21999 63252 66052
84210 03177 93159 49770 79937 15995 54707 91687 80746 60452 21335 38685 39753 36548
46162 17322 03841 17726 76069 01041 99568 30544 37616 42957 26935 75001 04245 89955
59384 24540 29071 68592 23472 32276 58979 78869 19199 45093 20526 94228 46566 89551
87155 41225 05573 39089 11981 19863 69660 20267 41889 30140 65388 59643 03436 45498
92755 77542 70065 92496 25203 53638 94891 71133 89291 34817 24799 81410 85019 47634
86346 96768 12386 92091 52975 70324 71392 68188 77801 22404 35480 49366 07709 32680
31208 62184 69256 74597 58575 06641 35885 21595 91023 56179 60711 00232 55111 63915
90619 83951 50839 76733 25608 25867 78206 94632 18795 72865 10654 70729 17063 51502
01300 51907 73529 61779 97027 64724 08518 77137 97836 09181 01704 24135 56843 85278
99973 02773 20931 66456 56438 13049 16658 79274 91428 28408 44025 23731 84614 75406
76474 73269 82883 54043 67120 81005 12790 64320 62847 93823 74338 79678 63656 11722
67524 26676 22663 87819 65792 05313 86751 68997 95700 15590 82478 81814 57247 57507
09845 26272 50434 04504 42294 02368 48702 83142 06382 83546 78610 66861 02109 96364
40157 08777 29476 40821 33344 55775 88482 90360 31612 34412 52570 98096 61520 18131

Random Number Table: Page 4

44430 95959 67929 98905 05977 11318 95296 43362 99164 58316 27744 19458 97432 36953
18390 00636 27340 47230 14118 13454 88887 62588 14927 57911 82074 09586 73933 07450
80342 88223 38021 15186 10250 98500 33748 28003 71797 13858 61115 72460 64983 87414
93564 21999 63252 66052 84210 03177 93159 49770 79937 15995 54707 91687 80746 60452
21335 38685 39753 36548 46162 17322 03841 17726 76069 01041 99568 30544 37616 42957
26935 75001 04245 89955 59384 24540 29071 68592 23472 32276 58979 78869 23434 59491
98203 35183 24243 03949 64832 82181 83249 80045 89658 60819 47337 61223 19566 44538
43065 74041 81113 86454 70432 18498 47742 33452 02880 68037 72568 12089 66968 75773
02476 22366 62696 88590 64023 37724 90063 33047 30652 84722 49069 82586 55478 63359
13157 63764 85386 73636 08885 03139 46933 88995 36252 21039 13562 35993 68700 97135
38388 14630 32788 78313 68296 24907 28516 91131 29843 40265 55883 35588 96472 13821
14889 11685 21298 65900 78977 92863 51205 76177 74704 05680 12753 18093 02071 50137
79381 65091 34520 99676 04208 43729 98608 07412 34115 27447 94335 20230 69105 69364
21702 38129 62291 16362 54151 14225 60560 94999 44797 95403 17025 05276 40524 08221
52015 20634 41333 52678 45201 67632 00340 28775 43469 46269 64428 09953 99935 56546
60155 22770 34924 71905 87522 67227 28111 18902 19971 16766 26379 97540 10616 24502
56287 07817 06344 37320 17834 23175 07153 55219 11021 70173 66159 31315 09289 48810
30247 12494 39197 59087 25975 25311 00744 01003 53342 69768 93931 48001 85790 45865
92199 26638 49878 27043 22107 10357 45606 39861 83654 52274 72973 84318 76841 99271
31979 33856 75109 77909 96067 41592 05017 61628 91795 54410 66564 03544 19161 98867
59751 50542 51610 48406 58019 29179 15698 29584 87927 39456 11425 42401 49474 54814
38792 86858 42660 01812 71241 62955 40929 80450 61887 44133 70836 90726 57614 56951
32384 06085 58423 01408 25570 53083 17430 50946 23839 31720 81518 58682 53746 41997
77245 71500 15293 57355 04612 15957 08480 30911 37061 65496 06748 09548 27707 46674
36656 93267 23434 59491 98203 35183 24243 03949 64832 82181 83249 80045 89658 60819
47337 61223 19566 44538 43065 74041 81113 86454 70432 18498 47742 33452 02880 68037
72568 12089 66968 75773 02476 22366 62696 88590 64023 37724 90063 33047 30652 84722
49069 82586 55478 63359 13157 63764 85386 73636 08885 03139 46933 88995 36252 21039
13562 35993 68700 97135 38388 14630 32788 78313 68296 24907 28516 91131 29843 40265
55883 35588 96472 13821 14889 11685 21298 65900 78977 92863 51205 76177 74704 05680
12753 18093 02071 50137 79381 65091 34520 99676 04208 43729 98608 07412 34115 27447
94335 20230 69105 69364 21702 38129 62291 16362 54151 14225 60560 94999 44797 95403
17025 05276 40524 08221 52015 20634 41333 52678 45201 67632 00340 28775 43469 46269
64428 09953 99935 56546 60155 22770 34924 71905 87522 67227 28111 18902 19971 16766
26379 97540 10616 24502 56287 07817 06344 37320 17834 23175 07153 55219 11021 70173
66159 31315 09289 48810 30247 12494 39197 59087 25975 25311 00744 01003 53342 69768
93931 48001 85790 45865 92199 26638 49878 27043 22107 10357 45606 39861 83654 52274
72973 84318 76841 99271 31979 33856 75109 77909 96067 41592 05017 61628 91795 54410
66564 03544 19161 98867 59751 50542 51610 48406 58019 29179 15698 29584 87927 39456
11425 42401 49474 54814 38792 86858 42660 01812 71241 62955 40929 80450 61887 44133
70836 90726 57614 56951 32384 06085 58423 01408 25570 53083 17430 50946 23839 31720
81518 58682 53746 41997 77245 71500 15293 57355 04612 15957 08480 30911 37061 65496
06748 09548 27707 46674 36656 93267 23434 59491 98203 35183 24243 03949 64832 82181
83249 80045 89658 60819 47337 61223 19566 44538 43065 74041 81113 86454 70432 18498
47742 33452 02880 68037 72568 12089 66968 75773 02476 22366 62696 88590 64023 37724

Random Number Table: Page 5

90063 33047 30652 84722 49069 82586 55478 63359 13157 63764 85386 73636 08885 03139
46933 88995 36252 21039 13562 35993 68700 97135 38388 14630 32788 78313 68296 24907
28516 91131 29843 40265 55883 35588 96472 13821 14889 11685 21298 65900 78977 92863
51205 76177 74704 05680 12753 18093 02071 50137 79381 65091 34520 99676 04208 43729
98608 07412 34115 27447 94335 20230 69105 69364 21702 38129 62291 16362 54151 14225
60560 94999 44797 95403 17025 05276 40524 08221 52015 20634 41333 52678 45201 67632
00340 28775 43469 46269 64428 09953 99935 56546 60155 22770 34924 71905 87522 67227
28111 18902 19971 16766 26379 97540 10616 24502 56287 07817 06344 37320 17834 23175
07153 55219 11021 70173 66159 31315 09289 48810 30247 12494 39197 59087 25975 25311
00744 01003 53342 69768 93931 48001 85790 45865 92199 26638 49878 27043 22107 10357
45606 39861 83654 52274 72973 84318 76841 99271 31979 33856 75109 77909 96067 41592
05017 61628 91795 54410 66564 03544 19161 98867 59751 50542 51610 48406 58019 29179
15698 29584 87927 39456 11425 42401 49474 54814 38792 86858 42660 01812 71241 62955
40929 80450 61887 44133 70836 90726 57614 56951 32384 06085 58423 01408 25570 53083
17430 50946 23839 31720 81518 58682 53746 41997 77245 71500 15293 57355 04612 15957
08480 30911 37061 65496 06748 09548 27707 46674 36656 93267 23434 59491 98203 35183
24243 03949 64832 82181 83249 80045 89658 60819 47337 61223 19566 44538 43065 74041
81113 86454 70432 18498 47742 33452 02880 68037 72568 12089 66968 75773 02476 22366
62696 88590 64023 37724 90063 33047 30652 84722 49069 82586 55478 63359 13157 63764
85386 73636 08885 03139 46933 88995 36252 21039 13562 35993 68700 97135 38388 14630
32788 78313 68296 24907 28516 91131 29843 40265 55883 35588 96472 13821 14889 11685
21298 65900 78977 92863 51205 76177 74704 05680 12753 18093 02071 50137 79381 65091
34520 99676 04208 43729 98608 07412 34115 27447 94335 20230 69105 69364 21702 38129
62291 16362 54151 14225 60560 94999 44797 95403 17025 05276 40524 08221 52015 20634
41333 52678 45201 67632 00340 28775 43469 46269 64428 09953 99935 56546 60155 22770
34924 71905 87522 67227 28111 18902 19971 16766 26379 97540 10616 24502 56287 07817
06344 37320 17834 23175 07153 55219 11021 70173 66159 31315 09289 48810 30247 12494
39197 59087 25975 25311 00744 01003 53342 69768 93931 48001 85790 45865 92199 26638
49878 27043 22107 10357 45606 39861 83654 52274 72973 84318 76841 99271 31979 33856
75109 77909 96067 41592 05017 61628 91795 54410 66564 03544 19161 98867 59751 50542
51610 48406 58019 29179 15698 29584 87927 39456 11425 42401 49474 54814 38792 86858
42660 01812 71241 62955 40929 80450 61887 44133 70836 90726 57614 56951 32384 06085
58423 01408 25570 53083 80399 19111 56091 45151 24856 85740 03089 04157 00953 10566
81726 68245 82131 40474 65445 63973 94948 02021 07361 91339 39405 68650 54359 23788
88944 93476 32997 87876 96680 23383 43273 83603 09498 84931 58632 10970 53955 51559
05630 69977 03493 76386 84267 34065 84672 06293 94544 29792 24047 67841 09902 57159
41946 34469 56900 89608 18043 59295 35537 53696 99221 89203 45814 49423 12039 50750
61173 76790 56496 17379 34728 35797 32592 42205 86808 99885 13770 72113 97085 95612
26588 33660 39001 22979 71045 00289 85999 55427 20584 25115 64636 19515 28320 55023
48355 15243 41137 90012 90271 42610 59036 83199 37269 75058 35133 81467 15907 65704
16311 37933 26183 61432 29129 72922 41542 62241 73586 66109 88540 21247 49682 64377
67177 85335 30860 20843 77454 81063 43678 55832 92812 08430 88135 49019 39810 40878
37674 47287 18447 31524 45410 77195 28724 27251 58227 38742 44083 28061 76126 31929
91080 87067 52223 30197 69718 51155 33401 60104 79995 46882 46219 21652 21911 74249
90676 14838 68909 06698 66772 13107 47546 70786 47951 43014 31265 66513 60768 04562

Random Number Table: Page 6

75317 87471 24452 40069 19775 80658 71449 72518 69313 78926 50087 36606 50491 08834
60364 32333 63309 70381 75722 59700 07766 63568 22720 92148 83863 61836 01357 82794
65041 91744 11634 78522 77858 53291 26992 79331 22315 46478 73990 38337 71854 44746
52628 02425 79590 74654 62904 98153 92408 36201 78263 25520 36865 29388 51819 57968
86403 27656 30456 48614 67581 57564 14175 44342 80399 19111 56091 45151 24856 85740
03089 04157 00953 10566 81726 68245 82131 40474 65445 63973 94948 02021 07361 91339
39405 68650 54359 23788 88944 93476 32997 87876 96680 23383 43273 83603 09498 84931
58632 10970 53955 51559 05630 69977 03493 76386 84267 34065 84672 06293 94544 29792
24047 67841 09902 57159 41946 34469 56900 89608 18043 59295 35537 53696 99221 89203
45814 49423 12039 50750 61173 76790 56496 17379 34728 35797 32592 42205 86808 99885
13770 72113 97085 95612 26588 33660 39001 22979 71045 00289 85999 55427 20584 25115
64636 19515 28320 55023 48355 15243 41137 90012 90271 42610 59036 83199 37269 75058
35133 81467 15907 65704 16311 37933 26183 61432 29129 72922 41542 62241 73586 66109
88540 21247 49682 64377 67177 85335 30860 20843 77454 81063 43678 55832 92812 08430
88135 49019 39810 40878 37674 47287 18447 31524 45410 77195 28724 27251 58227 38742
44083 28061 76126 31929 91080 87067 52223 30197 69718 51155 33401 60104 79995 46882
46219 21652 21911 74249 90676 14838 68909 06698 66772 13107 47546 70786 47951 43014
31265 66513 60768 04562 73181 93880 05225 97748 20179 52887 54764 96017 98816 16975
62500 25924 82535 12702 75317 87471 24452 40069 19775 80658 71449 72518 69313 78926
50087 36606 50491 08834 60364 32333 63309 70381 75722 59700 07766 63568 22720 92148
83863 61836 01357 82794 65041 91744 11634 78522 77858 53291 26992 79331 22315 46478
73990 38337 71854 44746 52628 02425 79590 74654 62904 98153 92408 36201 78263 25520
36865 29388 51819 57968 86403 27656 30456 48614 67581 57564 14175 44342 80399 19111
56091 45151 24856 85740 03089 04157 00953 10566 81726 68245 82131 40474 65445 63973
94948 02021 07361 91339 39405 68650 54359 23788 88944 93476 32997 87876 96680 23383
43273 83603 09498 84931 58632 10970 53955 51559 05630 69977 03493 76386 84267 34065
84672 06293 94544 29792 24047 67841 09902 57159 41946 34469 56900 89608 18043 59295
35537 53696 99221 89203 45814 49423 12039 50750 61173 76790 56496 17379 34728 35797
32592 42205 86808 99885 13770 72113 97085 95612 26588 33660 39001 22979 71045 00289
85999 55427 20584 25115 64636 19515 28320 55023 48355 15243 41137 90012 90271 42610
59036 83199 37269 75058 35133 81467 15907 65704 16311 37933 26183 61432 29129 72922
41542 62241 73586 66109 88540 21247 49682 64377 67177 85335 30860 20843 77454 81063
43678 55832 92812 08430 88135 49019 39810 40878 37674 47287 18447 31524 45410 77195
28724 27251 58227 38742 44083 28061 76126 31929 91080 87067 52223 30197 69718 51155
33401 60104 79995 46882 46219 21652 21911 74249 90676 14838 68909 06698 66772 13107
47546 70786 47951 43014 31265 66513 60768 04562 73181 93880 05225 97748 20179 52887
54764 96017 98816 16975 62500 25924 82535 12702 75317 87471 24452 40069 19775 80658
71449 72518 69313 78926 50087 36606 50491 08834 60364 32333 63309 70381 75722 59700
07766 63568 22720 92148 83863 61836 01357 82794 65041 91744 11634 72290 71627 47059
20761 73099 16084 40246 67759 32106 65622 38514 46396 96194 73358 68422 56673 91921
86176 29969 72031 19288 30633 23156 45587 51737 80172 21424 24224 42382 61350 51332
07943 38110 74167 12879 49859 38919 18624 79508 96857 97925 94721 04334 75495 62013
75899 34242 59213 57741 88717 95789 01130 85108 33174 62418 48128 17556 82712 87244
26765 81644 90448 17152 37042 77372 03266 78699 52400 04739 47723 45328 99398 63745
97262 70154 78035 27833 78440 00062 88312 23561 17815 61609 03671 50928 35715 28238

Random Number Table: Page 7

50668 83376 11811 53064 29306 47464 92989 82972 39583 43191 05807 44519 54941 70558
50264 11147 28497 29565 26360 35974 80576 93653 07539 65881 90853 89380 20356 27429
32769 16747 64813 94057 79767 49196 14352 18884 58404 13284 22088 48791 42123 09011
34906 83781 84040 36378 52805 76967 31037 68827 28901 75235 09675 59473 10079 31701
19952 55200 22897 66690 35310 56009 67354 59877 82308 15016 43451 58145 60945 79103
24629 14611 71222 74831 37446 49600 86580 02198 81903 42787 33578 34646 31442 41055
12216 25292 39178 70963 22492 21020 51996 32510 37851 21829 69895 25697 84849 80835
45991 23965 63486 44923 27169 53873 73763 40651 39987 15420 15679 68018 84444 08607
62677 00466 60541 06875 41314 64554 41719 36783 25033 60282 54536 98330 66950 87649
98994 91517 13947 46655 48532 89785 92585 10743 56268 19693 76304 06470 69086 81240
18220 33837 13543 74426 65218 66286 63081 72695 43855 30374 44260 02602 54132 26101
57077 64150 69490 53468 01534 57336 16488 85917 77631 55605 95125 76563 58809 85512
05402 72290 71627 47059 20761 73099 16084 40246 67759 32106 92577 66278 18617 61601
59206 13276 77623 11140 84032 91913 41711 92318 13940 02190 37438 31693 75487 17548
64805 49592 42115 64546 97254 25689 66942 43184 61342 06867 96849 53460 57069 19685
58397 68819 84436 64142 25025 42375 43443 40238 49852 94454 07531 21416 79759 04731
03258 34234 41306 46647 30625 78691 07935 93645 63074 28230 32761 72282 27162 35966
62669 56001 22889 48783 97658 97918 50256 66683 90845 44915 82705 42779 89113 23553
73350 23957 45579 33830 69078 36775 80568 49188 69887 81232 73755 96186 28893 57328
72023 74823 92981 38507 28489 85100 88709 51324 63478 00458 16076 95781 56665 47456
48524 45320 54933 26093 39170 53056 84841 36370 34898 65874 46388 51729 35707 83773
39575 98727 94713 59869 37843 77364 58801 41047 67751 87641 54529 53865 29298 29557
81896 98322 22485 76555 14344 74419 20753 55192 78432 55597 50661 38911 74159 68414
12208 80827 01526 12871 05394 27825 60533 62410 03663 06463 24621 70146 33570 90181
20348 82964 95118 32098 47715 27421 88304 79096 80164 76959 86573 57733 44252 58137
16480 68010 39979 70955 78027 83368 67346 15412 71214 30366 99795 91509 69482 09003
90441 72687 99390 19280 86168 85504 60937 34639 86977 29962 54124 81636 45984 79500
52392 60274 10071 87236 82300 70551 05799 00054 43847 85909 33166 44511 37034 59465
65614 94049 35302 38102 56260 75228 65210 21821 51988 88045 26757 63737 52797 32502
93386 10735 11803 08599 18212 89372 75891 89777 48120 73091 71619 02595 09667 15008
98986 47052 76296 62005 31434 96590 01122 40643 95522 04326 31030 50920 91250 17144
92577 66278 18617 61601 59206 13276 77623 11140 84032 91913 41711 92318 13940 02190
37438 31693 75487 17548 64805 49592 42115 64546 97254 25689 66942 43184 61342 06867
96849 53460 57069 19685 58397 68819 84436 64142 25025 42375 43443 40238 49852 94454
07531 21416 79759 04731 03258 34234 41306 46647 30625 78691 07935 93645 63074 28230
32761 72282 27162 35966 62669 56001 22889 48783 97658 97918 50256 66683 90845 44915
82705 42779 89113 23553 73350 23957 45579 33830 69078 36775 80568 49188 69887 81232
73755 96186 28893 57328 72023 74823 92981 38507 28489 85100 88709 51324 63478 00458
16076 95781 56665 47456 48524 45320 54933 26093 39170 53056 84841 36370 34898 65874
46388 51729 35707 83773 39575 98727 94713 59869 37843 77364 58801 41047 67751 87641
54529 53865 29298 29557 81896 98322 22485 76555 14344 74419 20753 55192 78432 55597
50661 38911 74159 68414 12208 80827 01526 12871 05394 27825 60533 62410 03663 06463
24621 70146 33570 90181 20348 82964 95118 32098 47715 27421 88304 79096 80164 76959
86573 57733 44252 58137 16480 68010 39979 70955 78027 83368 67346 15412 71214 30366
99795 91509 69482 09003 90441 72687 99390 19280 86168 85504 60937 34639 86977 29962

Random Number Table: Page 8

33166 44511 37034 59465 65614 94049 35302 38102 56260 75228 65210 21821 51988 88045
26757 63737 52797 32502 93386 10735 11803 08599 18212 89372 75891 89777 48120 73091
71619 02595 09667 15008 98986 47052 76296 62005 31434 96590 01122 40643 95522 04326
31030 50920 91250 17144 92577 66278 18617 61601 59206 13276 77623 11140 84032 91913
41711 92318 13940 02190 37438 31693 75487 17548 64805 49592 42115 64546 97254 25689
66942 43184 61342 06867 96849 53460 57069 19685 58397 68819 84436 64142 25025 42375
43443 40238 49852 94454 07531 21416 79759 04731 03258 34234 41306 46647 30625 78691
07935 93645 63074 28230 32761 72282 27162 35966 62669 56001 22889 48783 97658 97918
50256 66683 90845 44915 82705 42779 89113 23553 73350 23957 45579 33830 69078 36775
80568 49188 69887 81232 73755 96186 28893 57328 72023 74823 92981 38507 28489 85100
88709 51324 63478 00458 16076 95781 56665 47456 48524 45320 54933 26093 39170 53056
84841 36370 34898 65874 46388 51729 35707 83773 39575 98727 94713 59869 37843 77364
58801 41047 67751 87641 54529 53865 29298 29557 81896 98322 22485 76555 14344 74419
20753 55192 78432 55597 50661 38911 74159 68414 12208 80827 01526 12871 05394 27825
60533 62410 03663 06463 24621 70146 33570 90181 20348 82964 95118 32098 47715 27421
88304 79096 80164 76959 86573 57733 44252 58137 16480 68010 39979 70955 78027 83368
67346 15412 71214 30366 99795 91509 69482 09003 90441 72687 99390 19280 86168 85504
60937 34639 86977 29962 54124 81636 45984 79500 52392 60274 10071 87236 82300 70551
05799 00054 43847 85909 33166 44511 37034 59465 65614 94049 35302 38102 56260 75228
65210 21821 51988 69350 08062 45042 34102 13807 74691 92040 93108 89904 99517 70677
57196 71082 29425 54396 52924 83899 90972 96313 80291 28357 57601 43310 12739 77895
82427 21948 76827 85631 12335 32225 72555 98449 73882 47583 99921 42906 40511 94581
58928 92445 65337 73218 23016 73623 95244 83495 18743 12998 56792 98853 46110 30897
23420 45851 78559 06994 48247 24489 42647 88172 78154 34765 38374 00990 39702 50124
65741 45447 06330 23680 24748 21543 31156 75759 88836 02721 61064 86036 84563 15539
22611 27952 11930 59996 89240 74950 44379 09535 14066 53587 08467 17271 43974 37306
04194 30088 78963 79222 31561 47987 72150 26220 64009 24084 70418 04858 54655 05262
26884 15134 50383 18080 61873 30493 51192 62537 55060 77491 10198 38633 53328 56128
74286 19812 09794 66405 70014 32629 44783 81763 97381 77086 37970 28761 29829 26625
36238 07398 20475 34361 66146 17675 16203 47178 27693 33034 17012 65078 20880 80031
76018 41174 19148 58669 40106 22352 49056 68946 35833 35170 10603 10862 63200 79627
03790 57860 95649 55724 02058 36497 59737 36902 31965 20216 55464 49719 93513 62132
82831 94176 86699 09130 41838 43715 84968 87768 05926 51451 14875 71486 01653 64269
76423 13403 29020 08726 69609 60401 61469 58264 67877 39038 25557 39442 97785 49315
21284 52260 59332 64673 48651 96717 52519 11671 81100 72814 50787 90308 71746 53992
80695 00585 67473 66809 42242 15943 68282 11266 35429 62941 27288 60805 33697 41579
91376 68541 63605 51855 87104 81359 25152 67214 14471 25816 18339 40770 46919 75354
16607 19407 37565 56533 46515 03126 33293 69350 08062 45042 34102 13807 74691 92040
93108 89904 64825 67625 85783 04750 94733 51344 81510 17568 56280 93260 82320 62025
22909 40258 41326 38122 47735 18895 05414 19300 77642 02614 01141 32117 39190 44530
28508 76574 05818 91528 60957 26113 30645 70166 25045 33849 60552 80442 20772 46667
22100 95801 48139 91124 88728 42799 07146 40662 13554 21436 71234 21840 43462 31713
66961 61216 05009 47071 94328 79115 71638 94069 26777 55212 96464 72706 90865 36390
26372 82983 86592 49207 87919 98342 13959 93664 54548 71897 72965 69761 79374 23977
37053 50939 09282 34254 32781 63757 70829 76170 60148 08214 37458 23168 92596 57752

APPENDIX 3. Statistical Tables

Table 3.1. One and two-tailed critical values for the *t* distribution: the **T-Test**.

v	*2-tailed* α: *1-tailed* α:	*0.50* *0.25*	*0.30* *0.15*	*0.20* *0.10*	*0.10* *0.05*	*0.05* *0.025*	*0.02* *0.01*	*0.01* *0.005*	*0.005* *0.0025*	*0.002* *.001*	*0.001* *0.0005*
1		1.000	1.963	3.078	6.314	12.71	31.82	63.66	127.3	318.3	636.6
2		0.816	1.386	1.886	2.920	4.303	6.965	9.925	14.09	22.33	31.60
3		0.765	1.250	1.638	2.353	3.182	4.541	5.841	7.453	10.21	12.92
4		0.741	1.190	1.533	2.132	2.776	3.747	4.604	5.598	7.173	8.610
5		0.727	1.156	1.476	2.015	2.571	3.365	4.032	4.773	5.893	6.869
6		0.718	1.134	1.440	1.943	2.447	3.143	3.707	4.317	5.208	5.959
7		0.711	1.119	1.415	1.895	2.365	2.998	3.499	4.029	4.785	5.408
8		0.706	1.108	1.397	1.860	2.306	2.896	3.355	3.833	4.501	5.041
9		0.703	1.100	1.383	1.833	2.262	2.821	3.250	3.690	4.297	4.781
10		0.700	1.093	1.372	1.812	2.228	2.764	3.169	3.581	4.144	4.587
11		0.697	1.088	1.363	1.796	2.201	2.718	3.106	3.497	4.025	4.437
12		0.695	1.083	1.356	1.782	2.179	2.681	3.055	3.428	3.930	4.318
13		0.694	1.079	1.350	1.771	2.160	2.650	3.012	3.372	3.852	4.221
14		0.692	1.076	1.345	1.761	2.145	2.624	2.977	3.326	3.787	4.140
15		0.691	1.074	1.341	1.753	2.131	2.602	2.947	3.286	3.733	4.073
16		0.690	1.071	1.337	1.746	2.120	2.583	2.921	3.252	3.686	4.015
17		0.689	1.069	1.333	1.740	2.110	2.567	2.898	3.222	3.646	3.965
18		0.688	1.067	1.330	1.734	2.101	2.552	2.878	3.197	3.610	3.922
19		0.688	1.066	1.328	1.729	2.093	2.539	2.861	3.174	3.579	3.883
20		0.687	1.064	1.325	1.725	2.086	2.528	2.845	3.153	3.552	3.850
21		0.686	1.063	1.323	1.721	2.080	2.518	2.831	3.135	3.527	3.819
22		0.686	1.061	1.321	1.717	2.074	2.508	2.819	3.119	3.505	3.792
23		0.685	1.060	1.319	1.714	2.069	2.500	2.807	3.104	3.485	3.767
24		0.685	1.059	1.318	1.711	2.064	2.492	2.797	3.091	3.467	3.745
25		0.684	1.058	1.316	1.708	2.060	2.485	2.787	3.078	3.450	3.725
26		0.684	1.058	1.315	1.706	2.056	2.479	2.779	3.067	3.435	3.707
27		0.684	1.057	1.314	1.703	2.052	2.473	2.771	3.057	3.421	3.690
28		0.683	1.056	1.313	1.701	2.048	2.467	2.763	3.047	3.408	3.674
29		0.683	1.055	1.311	1.699	2.045	2.462	2.756	3.038	3.396	3.659
30		0.683	1.055	1.310	1.697	2.042	2.457	2.750	3.030	3.385	3.646
40		0.681	1.050	1.303	1.684	2.021	2.423	2.704	2.971	3.307	3.551
50		0.679	1.047	1.299	1.676	2.009	2.403	2.678	2.937	3.261	3.496
60		0.679	1.045	1.296	1.671	2.000	2.390	2.660	2.915	3.232	3.460
80		0.678	1.043	1.292	1.664	1.990	2.374	2.639	2.887	3.195	3.416
100		0.677	1.042	1.290	1.660	1.984	2.364	2.626	2.871	3.174	3.390
120		0.677	1.041	1.289	1.658	1.980	2.358	2.617	2.860	3.160	3.373
∞		0.674	1.036	1.282	1.645	1.960	2.326	2.576	2.807	3.090	3.291

Table 3.2. Two-tailed critical values for the **Pearson Correlation** coefficient r.
Degrees of freedom = n pairs – 2.

α **df**	***0.10***	***0.05***	***0.02***	***0.01***
1	0.988	0.997	0.9995	0.9999
2	0.900	0.950	0.980	0.990
3	0.805	0.878	0.934	0.959
4	0.729	0.811	0.882	0.917
5	0.669	0.754	0.833	0.874
6	0.622	0.707	0.789	0.834
7	0.582	0.666	0.750	0.798
8	0.549	0.632	0.716	0.765
9	0.521	0.602	0.685	0.735
10	0.497	0.576	0.658	0.708
11	0.476	0.553	0.634	0.684
12	0.458	0.532	0.612	0.661
13	0.441	0.514	0.592	0.641
14	0.426	0.497	0.574	0.623
15	0.412	0.482	0.558	0.606
16	0.400	0.468	0.542	0.590
17	0.389	0.456	0.528	0.575
18	0.378	0.444	0.516	0.561
19	0.369	0.433	0.503	0.549
20	0.360	0.423	0.492	0.537
21	0.352	0.413	0.482	0.526
22	0.344	0.404	0.472	0.515
23	0.337	0.396	0.462	0.505
24	0.330	0.388	0.453	0.496
25	0.323	0.381	0.445	0.487
26	0.317	0.374	0.437	0.479
27	0.311	0.367	0.430	0.471
28	0.306	0.361	0.423	0.463
29	0.301	0.355	0.416	0.456
30	0.296	0.349	0.409	0.449
35	0.275	0.325	0.381	0.418
40	0.257	0.304	0.358	0.393
45	0.243	0.288	0.338	0.372
50	0.231	0.273	0.322	0.354
60	0.211	0.250	0.295	0.325
70	0.195	0.232	0.274	0.303
80	0.183	0.217	0.256	0.283
90	0.173	0.205	0.242	0.267
100	0.164	0.195	0.230	0.254

Table 3.3. One-tailed critical values for **Chi Square** distribution; for two- tailed just double the probability.

α **df**	***0.50***	***0.10***	***0.05***	***0.025***	***0.01***	***0.005***	***0.001***
1	0.455	2.706	3.841	5.024	6.635	7.879	10.828
2	1.386	4.605	5.991	7.378	9.210	10.597	13.816
3	2.366	6.251	7.815	9.348	11.345	12.838	16.266
4	3.357	7.779	9.488	11.143	13.277	14.860	18.467
5	4.351	9.236	11.070	12.833	15.086	16.750	20.515
6	5.348	10.645	12.592	14.449	16.812	18.548	22.458
7	6.346	12.017	14.067	16.013	18.475	20.278	24.322
8	7.344	13.362	15.507	17.535	20.090	21.955	26.124
9	8.343	14.684	16.919	19.023	21.666	23.589	27.877
10	9.342	15.987	18.307	20.483	23.209	25.188	29.588
11	10.341	17.275	19.675	21.920	24.725	26.757	31.264
12	11.340	18.549	21.026	23.337	26.217	28.300	32.909
13	12.340	19.812	22.362	24.736	27.688	29.819	34.528
14	13.339	21.064	23.685	26.119	29.141	31.319	36.123
15	14.339	22.307	24.996	27.488	30.578	32.801	37.697
16	15.338	23.542	26.296	28.845	32.000	34.267	39.252
17	16.338	24.769	27.587	30.191	33.409	35.718	40.790
18	17.338	25.989	28.869	31.526	34.805	37.156	42.312
19	18.338	27.204	30.144	32.852	36.191	38.582	43.820
20	19.337	28.412	31.410	34.170	37.566	39.997	45.315
21	20.337	29.615	32.671	35.479	38.932	41.401	46.797
22	21.337	30.813	33.924	36.781	40.289	42.796	48.268
23	22.337	32.007	35.172	38.076	41.638	44.181	49.728
24	23.337	33.196	36.415	39.364	42.980	45.559	51.179
25	24.337	34.382	37.652	40.646	44.314	46.928	52.620
26	25.336	35.563	38.885	41.923	45.642	48.290	54.052
27	26.336	36.741	40.113	43.195	46.963	49.645	55.476
28	27.336	37.916	41.337	44.461	48.278	50.993	56.892
29	28.336	39.087	42.557	45.722	49.588	52.336	58.301
30	29.336	40.256	43.773	46.979	50.892	53.672	59.703
31	30.336	41.422	44.985	48.232	52.191	55.003	61.098
32	31.336	42.585	46.194	49.480	53.486	56.328	62.487
33	32.336	43.745	47.400	50.725	54.776	57.648	63.870
34	33.336	44.903	48.602	51.966	56.061	58.964	65.247
35	34.336	46.059	49.802	53.203	57.342	60.275	66.619

Table 3.4. Critical values for **Mann-Whitney U**.

Mann-Whitney U: 2-tailed

2-tailed		**n_2**																
n_2	α	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
3	***.05***		0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
	.01						0	0	0	1	1	1	2	2	2	2	3	3
4	***.05***	0	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	14
	.01			0	0	1	1	2	2	3	3	4	5	5	6	6	7	8
5	***.05***		2	3	5	6	7	8	9	11	12	13	14	15	17	18	19	20
	.01		0	1	1	2	3	4	5	6	7	7	8	9	10	11	12	13
6	***.05***			5	6	8	10	11	13	14	16	17	19	21	22	24	25	27
	.01			2	3	4	5	6	7	9	10	11	12	13	15	16	17	18
7	***.05***				8	10	12	14	16	18	20	22	24	26	28	30	32	34
	.01				4	6	7	9	10	12	13	15	16	18	19	21	22	24
8	***.05***					13	15	17	19	22	24	26	29	31	34	36	38	41
	.01					7	9	11	13	15	17	18	20	22	24	26	28	30
9	***.05***						17	20	23	26	28	31	34	37	39	42	45	48
	.01						11	13	16	18	20	22	24	27	29	31	33	36
10	***.05***							23	26	29	33	36	39	42	45	48	52	55
	.01							16	18	21	24	26	29	31	34	37	39	42
11	***.05***								30	33	37	40	44	47	51	55	58	62
	.01								21	24	27	30	33	36	39	42	45	48
12	***.05***									37	41	45	49	53	57	61	65	69
	.01									27	31	34	37	41	44	47	51	54
13	***.05***										45	50	54	59	63	67	72	76
	.01										34	38	42	45	49	53	57	60
14	***.05***											55	59	64	69	74	78	83
	.01											42	46	50	54	58	63	67
15	***.05***												64	70	75	80	85	90
	.01												51	55	60	64	69	73
16	***.05***													75	81	86	92	98
	.01													60	65	70	74	79
17	***.05***														87	93	99	105
	.01														70	75	81	86
18	***.05***															99	106	112
	.01															81	87	92
19	***.05***																113	119
	.01																93	99
20	***.05***																	127
	.01																	105

Mann-Whitney U: 1-tailed

1-tailed		**n_2**																
n_2	**α**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
3	***.05***	0	1	2	2	3	3	4	5	5	6	7	7	8	9	9	10	11
	.01				0	0	1	1	1	2	2	2	3	3	4	4	4	5
4	***.05***	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18
	.01		0	1	1	2	3	3	4	5	5	6	7	7	8	9	9	10
5	***.05***		4	5	6	8	9	11	12	13	15	16	18	19	20	22	23	25
	.01		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
6	***.05***			7	8	10	12	14	16	17	19	21	23	25	26	28	30	32
	.01			3	4	6	7	8	9	11	12	13	15	16	18	19	20	22
7	***.05***				11	13	15	17	19	21	24	26	28	30	33	35	37	39
	.01				6	7	9	11	12	14	16	17	19	21	23	24	26	28
8	***.05***					15	18	20	23	26	28	31	33	36	39	41	44	47
	.01					9	11	13	15	17	20	22	24	26	28	30	32	34
9	***.05***						21	24	27	30	33	36	39	42	45	48	51	54
	.01						14	16	18	21	23	26	28	31	33	36	38	40
10	***.05***							27	31	34	37	41	44	48	51	55	58	62
	.01							19	22	24	27	30	33	36	38	41	44	47
11	***.05***								34	38	42	46	50	54	57	61	65	69
	.01								25	28	31	34	37	41	44	47	50	53
12	***.05***									42	47	51	55	60	64	68	72	77
	.01									31	35	38	42	46	49	53	56	60
13	***.05***										51	56	61	65	70	75	80	84
	.01										39	43	47	51	55	59	63	67
14	***.05***											61	66	71	77	82	87	92
	.01											47	51	56	60	65	69	73
15	***.05***												72	77	83	88	94	100
	.01												56	61	66	70	75	80
16	***.05***													83	89	95	101	107
	.01													66	71	76	82	87
17	***.05***														96	102	109	115
	.01														77	82	88	93
18	***.05***															109	116	123
	.01															88	94	100
19	***.05***																123	130
	.01																101	107
20	***.05***																	138
	.01																	114

Table 3.4. Critical values for the **Spearman Rank Correlation** coefficient r_s.

n	*2-tailed α:* *1-tailed α:*	*0.50* *0.25*	*0.20* *0.10*	*0.10* *0.05*	*0.05* *0.025*	*0.02* *0.01*	*0.01* *0.005*
4		0.600	1.000	1.000			
5		0.500	0.800	0.900	1.000	1.000	
6		0.371	0.657	0.829	0.886	0.943	1.000
7		0.321	0.571	0.714	0.786	0.893	0.929
8		0.310	0.524	0.643	0.738	0.833	0.881
9		0.267	0.483	0.600	0.700	0.783	0.833
10		0.248	0.455	0.564	0.648	0.745	0.794
11		0.236	0.427	0.536	0.618	0.709	0.755
12		0.217	0.406	0.503	0.587	0.678	0.727
13		0.209	0.385	0.484	0.560	0.648	0.703
14		0.200	0.367	0.464	0.538	0.626	0.679
15		0.189	0.354	0.446	0.521	0.604	0.654
16		0.182	0.341	0.429	0.503	0.582	0.635
17		0.176	0.328	0.414	0.485	0.566	0.615
18		0.170	0.317	0.401	0.472	0.550	0.600
19		0.165	0.309	0.391	0.460	0.535	0.584
20		0.161	0.299	0.380	0.447	0.520	0.570
21		0.156	0.292	0.370	0.435	0.508	0.556
22		0.152	0.284	0.361	0.425	0.496	0.544
23		0.148	0.278	0.353	0.415	0.486	0.532
24		0.144	0.271	0.344	0.406	0.476	0.521
25		0.142	0.265	0.337	0.398	0.466	0.511
26		0.138	0.259	0.331	0.390	0.457	0.501
27		0.136	0.255	0.324	0.382	0.448	0.491
28		0.133	0.250	0.317	0.375	0.440	0.483
29		0.130	0.245	0.312	0.368	0.433	0.475
30		0.128	0.240	0.306	0.362	0.425	0.467
31		0.126	0.236	0.301	0.356	0.418	0.459
32		0.124	0.232	0.296	0.350	0.412	0.452
33		0.121	0.229	0.291	0.345	0.405	0.446
34		0.120	0.225	0.287	0.340	0.399	0.439
35		0.118	0.222	0.283	0.335	0.394	0.433
36		0.116	0.219	0.279	0.330	0.388	0.427
37		0.114	0.216	0.275	0.325	0.383	0.421
38		0.113	0.212	0.271	0.321	0.378	0.415
39		0.111	0.210	0.267	0.317	0.373	0.410
40		0.110	0.207	0.264	0.313	0.368	0.405