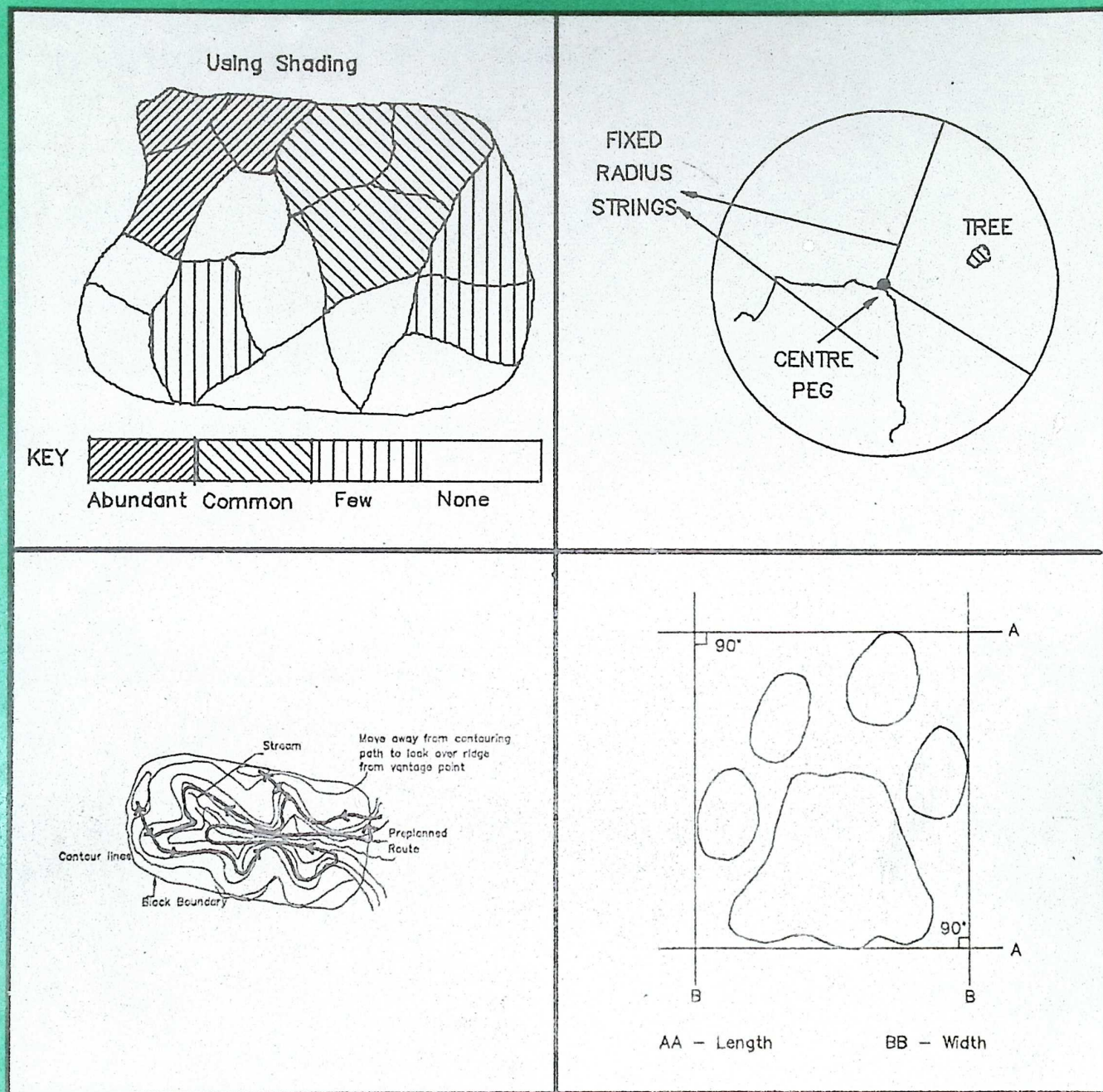


TECHNIQUES FOR WILDLIFE CENSUS IN INDIA

A FIELD MANUAL



W.A. Rodgers

WILDLIFE INSTITUTE OF INDIA
New Forest, Dehra Dun - 248 006, India

1991

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Technical Manual: TM-2

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The **Wildlife Institute of India (WII)** is an autonomous institution of the Ministry of Environment & Forests, Government of India, with a mandate to strengthen field conservation in India by providing trained professionals as wildlife scientists and managers and by providing scientific information. To this end the Institute conducts regular postgraduate and inservice, long and short term courses. The Institute has an elaborate field based wildlife research programme addressing biological, management and human dimensions aspects, conforming to national conservation priorities. Publishing information of value for field biologists and managers is also an important WII activity.

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First published : January 1991.

Published by Wildlife Institute of India, Dehradun.

Designed and produced by 'Environment Today',
184-B, Sheikh Sarai-I, New Delhi - 110 017.

PREFACE

This manual is a compilation of practical field techniques for one specific aspect of wildlife management: Census Operations. The manual is a response to requests to the Wildlife Institute of India from wildlife managers and biologists for information on census methodology.

Census operations form a significant part of a wildlife manager's duties in Indian protected areas and, increasingly, biologists are quantifying wildlife populations. A problem for such field personnel is that there is a lack of easily available literature dealing with wildlife census. A second problem is that when such literature is available it often deals with situations in North America or the African savannahs, and may have little relevance to conditions in India. Lastly, many texts dealing with census techniques are highly mathematical, with little detail on implementing the field operation - they are written for the specialists, not the managers.

This manual aims to fill the need for a practical guide to census techniques of potential value to the manager and biologist in India. A variety of techniques are chosen, many of their advantages and disadvantages are explained. Most of them have already been tested under field conditions by the staff and trainees of this Institute. Techniques are explained in simple terms, avoiding mathematics as much as possible. Analysis of census results does require some simple mathematics; and the interpretation of results, "has there been a population increase or not?" needs the ability to calculate a statistical confidence limit around the mean. Appendices cover the necessary statistical techniques. There is a section introducing the literature to wildlife census (section 4). References are rarely cited in the text.

This is the first full edition of this manual. It is our intention to add to it and to refine the descriptions. This is best done with the assistance of yourselves - the users. Your cooperation in suggesting possible improvements - in clarity of expression, thoroughness of description and even extra techniques is requested. This version follows from an original draft prepared in 1986 and refined following census workshops held in 1986 and 1987 in Sariska Tiger Reserve, Rajasthan. The opportunity was taken to reword some techniques and include new sections. Further sections were added prior to the Dachigam High Altitude Census Workshop in October 1988.

We still do not feel the manual is complete - we would like to include more actual field examples from Indian protected areas. But for this we need the help of wildlife managers and biologists; the potential users of the manual. Initial comment on the manual has been encouraging, but we would like information on the utility of the methods. So we again request you, please send information on actual census operations. We will happily acknowledge all contributions.

ACKNOWLEDGEMENTS

This manual has had a gestation period of almost five years with several drafts on the way ! There are obviously a host of people to thank for assistance and support. My colleagues at the Institute, Dr. A.J.T. Johnsingh and Shri V. B. Sawarkar have helped since the very first census workshop in November 1986, and have overseen the field trials of many of the techniques mentioned in the text. To them I owe the greatest thanks.

Trainees, students and research fellows of the Institute have used several of the techniques and have reported back on their strengths and weaknesses. Some colleagues have helped in writing specialist sections, and Dr. Ajith Kumar and Nima Manjrekar undertook the arduous task of reading a final draft (and finding errors). The Director of the Wildlife Institute of India provided continuous support and Shri Kishore Rao much needed push at the last moments!

Many people have laboured to produce the manual, Mr. Ashok Sen typed the very first draft and Ms. S. Dawson drew many diagrams. Later versions were ably produced by Mr. R.N. Tyagi, Mr. V. Sukumar and drawings by Mr. R. Thapa, M. Agarwal and D. Sharma. The final product was produced by Shri Akhil Chandra of 'Environment Today,' New Delhi.

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HOW TO USE THIS MANUAL or THE SELECTION OF CENSUS METHODS

A. Which Sections to Read

1. All users should read sections 1.0 - 1.3, the introductory comments explaining much of the terminology and rationale behind the census techniques. All users should scan the list of contents and sections of interest. The first appendix introduces sampling and should be looked at.
2. All users should know exactly why they want to do a census. Questions of which are key species, which are optimum months for field operations, what level of resources are available etc., should be known before the choice of methods are finalised.
3. Census objectives fall into four broad categories. Different techniques are useful for each category. These are:

Survey of geographical distribution and abundance in poorly known areas	Sections 2.1.1, 2.1.3 (part), 2.4.5, 2.4.6, 2.4.7
Survey of distribution and abundance by habitat, and basic population monitoring	Sections 2.1.2, 2.1.3, 2.1.5, 2.1.6, 2.2.1, 2.3.2
Determination of population size, either of protected area or of study area,	Sections 2.1.4, 2.1.5, 2.2.1, 2.2.2, 2.3.1, 2.3.2, 2.3.3, 2.3.4, 2.4.6, 2.4.7
Assessing animal density response to management inputs	Sections 2.1.2, 2.1.3, 2.1.4, 2.3.1, 2.4.1, 2.4.3

4. All users should read section 3, discussing the use and presentation of census results.

Note: It is stressed that this is a practical manual, not a full textbook. Persons planning elaborate census programmes should seek help from knowledgeable ecologists and statisticians.

All methods need practice in the form of field testing, staff training etc. before formal operations. Usually there is no perfect or ideal method. Most choice of method is a compromise. Often two or more methods may be necessary to cover the range of species and habitats.

B. Census Methods in Common Use Today

1. *Carnivores*

For large carnivores (tigers and leopards) the pugmark census (section 2.2.1) is universally used. For lion in Gir Wildlife Sanctuary census involves counting lions seen at waterholes and baits in 24 hours (section 2.1.4). There is no reason why tiger and leopard should not be counted at waterholes where this method is used for ungulates, as well as by pugmarks.

No abundance surveys have been made for smaller felids in India, or other small carnivores.

Rare animals like dhole, wolf and snow leopard have been assessed by individual recognition during intensive surveys and studies, usually in small study areas.

2. *Ungulates in General*

Two major sets of technique are in use by protected area managers:

- a) Waterhole counts, (section 2.1.4) are used in more arid areas which have a finite number of distinct waterholes in summer. Examples are: Ranthambhore, Tadoba, Bandipur. Details differ and there are major problems with knowing the frequency with which animals drink, and in knowing the repeatability of results. If results are consistent over three repetitions in a short time period then the results could be acceptable as an index to trends.
- b) Block counts, (section 2.3.1, but usually done as a total count, section 2.4.3). Several methodologies are used. These include the experienced guess by block or beat staff about animals in their compartments or census blocks, to a slightly more objective given time period (a few days) for beat staff to survey their blocks and reach an informed guess as to animal numbers. Increasingly, however, a specific search is made on a particular day in each block to actually count animals. In some areas the count is repeated. In some areas the block sizes are very large (5-10 km²) and could not be covered by a team in one day. In some areas a sample of smaller units is also counted to 'correct' the extensive counts.

Biologists (who rarely have the resources to mount block counts over large areas) have used a combination of transect counts, by vehicle and by foot, using several different estimators (see sections 2.3.2, 2.3.3).

3. *Specific Target Animals*

Many species or communities of species will need specialised techniques, for example primates (section 2.4.9), crocodiles and turtles (section 2.4.8), birds (section 2.4.10) and ungulates in the Himalayas or Evergreen Forest habitats (section 2.4.6 and 2.4.7).

4. *Rare Species; i.e. Species of Very Low Density or Very Low Visibility*

These are problematical and may not be amenable to detailed census; a subjective abundance rating may be all that is possible. Sometimes a detailed survey of intensive study sites plus a very much more generalised distribution survey may be appropriate, e.g. surveys of bustards, pheasants etc.

C. Short Cuts to Technique Selection

This section is written in response to requests from many past Wildlife Management Trainees.

1. *Estimation of Population Size*

a) Large Mammals:

Block Counts in small units, or at least a sample of small units, and use this sample to correct larger counts.

If area is dry and has few water points then consider use of *Water Hole Census* as well as less frequent use of block counts.

b) Carnivores:

Pug Mark Counts, frequent practice, using trained people.

c) Rare Species:

Total Counts in small areas and then general survey of total area.

Individual Recognition, map locations and times of sightings, keep a recognition file.

d) Birds, Reptiles:

See appropriate sections.

2. *Monitoring Population Abundance and Distribution*

a) *Roadside/Footpath Monitoring* of sightings or evidences.

3. *Assessing Reaction to Management Inputs*

a) *Dung Surveys* for small areas.

Introduction to Census for Indian Wildlife

1.1 INTRODUCTION

What is a Census?

Census in wildlife terminology deals with the estimation of abundance of animal (and plant) populations. The very simple set of descriptive adjectives: "absent, rare, occasional, common, abundant" is a measure of abundance of a species or population. It should be noted that for many species in India we do not even have this level of information for most protected areas! This sort of census does not depend on seeing the actual species in question, information can be collected on evidence of that animal's presence, e.g. tracks, dung, calls, feeding, nesting etc.

Census methods can thus be split into those dealing with observations on actual individuals and those based on other evidences, a distinction sometimes referred to as direct and indirect census. A census can be based on qualitative criteria: e.g. none, few, many; or based on quantitative measurements e.g. 0, 10, 52 etc.

A further division of census operations is into those that are aimed purely at determining trends or indices of population growth, and those that are aimed at actual population numbers. For example stating that an average of 5.2 chital were seen per kilometre of forest road in 1984, but 8.1 were seen in 1986, suggests there is an increase in population size, but it says nothing about the actual size of the population in that area, which could be 100 or 1000 animals! In most cases wildlife managers need information on trends so as to evaluate management practice and inputs, e.g. the population increased by 14% in two years. Information on population actual size e.g. "3026 chital in xyz sanctuary" is of little further value for management (even though administrators and laymen like to talk in real figures), and is a very much more difficult statistic to obtain.

Methods can be aimed at finding an actual number in a distinct area - population size; or the number per unit of habitat - population density, e.g. 4.2 animals per sq km. Densities can also be indices based on indirect evidences e.g. 323 groups of pellets per hectare. Many people find

density data to be more useful when making comparisons. For example telling us there are 16,000 chital in Kanha National Park and 3,000 in Ranthambhore National Park does not tell us very much about the biology of chital or of the two national parks. Statements such as Kanha has a density of 18 chital per sq km and Ranthambhore 7 per sq km is more informative. This becomes more so if related to habitat, e.g. in Ranthambhore there are 300 chital per sq km around the lakes in summer and <2 per sq km in the dry woodlands. This is an example of ecological density information.

This last point stresses the importance of knowing the pattern of distribution of abundance. Where are the animals located, where is the high density zone, where is the dry season concentration area, how does animal density distribution respond to increasing water availability? etc. are all examples of useful questions requiring knowledge of distribution.

Comparisons with Forest Inventory

Forest officers have considerable experience in estimating tree density, a major component of forest inventory, which is a science of mathematical complexity, involving careful design and planning procedures. Trees however stand still and are easily visible, they do not vary greatly from year to year. The procedures are going to be even more difficult with individuals which are of low density, which are often difficult to see (nocturnal, shy, or flee or hide), which can fluctuate widely in numbers and distribution from season to season and year to year, and can sometimes fight back!

The careful planning of a census exercise and the interpretation of conclusions from the results are thus every bit as important as the field operations and data analysis.

Introducing Census Techniques:

Census operations form the most obvious example of a modern-day wildlife manager using biological techniques in formal work programmes. Virtually every protected area has had a wildlife census, however rudimentary, at sometime in its past.

One of the most frequent questions asked about an area is "how many animals are there". One of the most important questions for a wildlife manager to answer is "are animal populations increasing or decreasing in size, and are they responding to management inputs". Both of these questions require census technology for their answer.

Census methods can vary from those using very elementary presence/ absence criteria to those involving highly complicated mathematical and statistical techniques in their design and analysis. It is the increasing frequency of the latter in many ecological and wildlife texts and journals that deter many people from investigating census methodologies in more detail. This need not be so, provided that the wildlife manager has a clear understanding of what he wants from a census, of the assumptions that are made about the interactions between observer, animals and habitats, and of the limitations of the data and conclusions.

The concepts and techniques that follow are designed to be used by managers in India's protected area network. Methods are, in some cases, adaptations of those already in use in India. Many of them are robust in that they are based on simple assumptions and can easily be modified to suit local conditions.

Census or Inventory

These are different things, but may be confused. A census deals with patterns of abundance of selected species. An inventory is a listing of all species present, which may involve considerable effort in capture and identification. The frequency of encounter of species during an inventory may form the basis of a simple census. In some places in the world, however, the word "inventory" does mean an abundance estimate or census.

1.2 PLANNING A CENSUS OPERATION

Background

Many factors are important in planning a census, e.g. time of year, key species, methods to use etc., but none are so fundamental as the questions of "why do I want to do a census" and "to what use do I want to put the census results". These factors are considered in this section.

Why do I want a census?

In many cases the answer is "because I have been instructed to do so" or "we have always had a census programme here"; this is unfortunate and does not help plan a useful census, but it is a fact of life. Reasons to undertake a census should be, "so as to give me more understanding of the

area, its animals, and its ecology" or "so I can evaluate management actions and or problems which may need management action". Whilst a protected area may have some 6-12 large mammal species, plus up to 50 lesser mammals, not all of these are equally important in management programmes. Only a few, known as 'key species' are of real importance. For some areas, birds or reptiles may be the key species, e.g. bustard, geese, herons, pheasants, gharial, turtles.

Key Species

Many protected areas have been especially created to conserve one or a few species considered nationally or internationally important. The National Chambal Sanctuary for gharial is an example. Some species are endangered locally or nationally, others are ecologically important or dominant in that area, such as the tiger or elephant, others form an important element of predator prey base such as chital, others are a favoured target of tourists, such as gaur. All of these may require specific management inputs and so may be considered as a key species for planning a census. For example a block count operation in a reserve in central India may have visibility parameters set for sambar and chital, which are relatively easily seen; barking deer, which is smaller and more secretive, would be greatly under-counted by such a count. To design a census for such a species would require far greater man-power and financial resources. As the barking deer is not a key species, less accurate data are to be expected and considered acceptable.

What are the census data to be used for?

A common requirement of a census is that it be used to determine change in population size from time to time. Usually this is from year to year, but may be before and after management operations such as: a fire or installing water or silvicultural tending operations etc. Comparisons could also be between two areas, for example comparing a core and a buffer zone, or sal and teak forest or natural forest and plantation etc.

If the purpose of a census is comparison then the data ought to be precise enough to detect differences. An elephant population may grow at a maximum rate of 4% per annum. A census operation which has precision limits of 10% (which would be a very good census!) would not detect significant changes over at least four years.

In many cases a simple index of density using dung counts may be the most efficient way to show change. For example counting pellets in a series of quadrats in two areas would be a way of showing difference in chital use of those two areas.

Four main types of census operation

Brockelman and Ali (1987) usefully describe three broad

categories of census operation in common use in wildlife studies; I add a fourth. These are:

Distributional Surveys: The planning of conservation inputs or improved management for species of concern, requires knowledge of the distribution of that species, preferably with some degree of knowledge of general abundance, e.g. "common here, rare there". Sometimes this is the initial 'broad survey' prelude to more detailed study in specific high density areas.

Population Estimation and or Monitoring: Here the interest is in obtaining an estimate of the total population in a region of concern, e.g. a wildlife protected area. The demarcation of the region of concern is the first step, followed by a choice of total count or sample count methodologies.

Intensive Study Areas: Here the census operation is often part of a more detailed biological investigation of a species, focusing on a small area or a small group of individuals.

Sometimes a study may incorporate all three categories, starting with the broad survey, undertaking a population density estimate, and then concentrating on a small group of animals.

Management Response Survey: Here management may have undertaken changes in part of the protected area, e.g. removed cattle, or stopped fire, or put in dry season water. It is useful to determine the response of animals, in terms of density, to these inputs. Such investigation need not involve a full scale census but can be localised monitoring including dung surveys for example.

What is an 'efficient' census method?

An efficient census method is one which collects the required information with the best level of accuracy and precision for the given quantum of time, funds and man power. These two parameters are defined in appendix 5.1.

What is the best time of year for a census?

There is no one answer to this question, it depends on the circumstances in each case. In the rains, access and poor visibility may restrict observer movement and ability to see animals. Immediately after the rains there will be adequate food and water resources, and animals are more likely to be evenly or randomly distributed, a pattern which is a common pre-requisite for many census methods. But this spreads density more evenly; for rare species, census may be easier if they were concentrated into a particular area. For a waterhole census the best time would be the height of the dry season when water is limiting - note however the emergence of the pre-rains flush of tree leaf may reduce some animals dependence on free water. The fire season and timber working season may cause frequent disturbances in distribution patterns making census more difficult.

What are the infrastructural requirements for a census?

Each method has its own set of requirements, e.g. adequate motorable tracks representative of the total area and which reach most parts of a reserve are needed for a vehicle transect census. Adequate trained man power is a frequent constraint to census work. All staff participating should be literate, be good observers, and have some level of prior training or practice. Often it is better to use a few good and interested people for a longer time period, than try to use a large number of poorly trained people at one time. People require funds, and a census involving a lot of man power is expensive. Funds should be specifically earmarked for census operations.

How often should a census be carried out?

This depends on the objectives of the census, but for species of conservation importance, at least every second year should be aimed at. Kaziranga counts rhinos every 6 years, Gir counts lions every 5 years; intervals I consider too long; a population could be greatly depleted in that time. For methods with little knowledge of accuracy and precision, I would have more reliance in a method which showed:

Year 1	902	animals		Year 1	902 animals
" 2	968	"	than one		and no information
" 4	974	"	which went	until	
" 6	1067	"		Year 6	1067 "

It may not be necessary to have counts of equal intensity every year. For example large scale actual counts every 3 years could be interspersed with less intensive dung counts or lesser area counts in intervening years, provided these are also run in major years as a means of control.

Census design and sample design

These two components of many census operation are often confused. The objective of census design is to obtain the best estimate of the numbers of individuals in each counting (sample) unit. The objective of sample design is to obtain a set of counting (sample) units representative of the statistical population. Both are important. Sample design may need the advice of a statistician, see appendices 5.1, 5.2.

A bureaucratic or paper census

Finally, a word on a difficult topic. Indian wildlife conservation has several stories of census results being manipulated to show small annual increments every year (5-15%). This is in response to expectations of audit minded bureaucrats that animal populations which are being expensively managed should never show a decrease. This is of course ecological nonsense. Given great fluctuations in annual rainfall it is to be expected that ungulate populations will show great fluctuations in mortality and natality response. Populations which are close to carrying capacity will exhibit no long

term trend of increase and will fluctuate around a mean figure, showing small increases and decreases. Populations may fluctuate due to random processes. For example a population of 20 tigers may have 4 females giving birth at the same time, the population could reach 30-32. One expects a large proportion of cubs to die, maybe only one per litter survives to adulthood. The population may "crash" to 22-24. This is normal, and bureaucrats must be shown that this is normal. Nobody gains if figures are falsified.

If figures are changed then ludicrous patterns may follow. One major tiger reserve showed a steady increase in sambar over the years from below 10,000 to over 14,000. When the manager changed, the number of sambar reduced to 3,500. This is not scientific management!

Finally census results become a laughing stock if results are obviously impossible. Stating the sex ratios of pythons and porcupines from waterhole counts, at night, with no binoculars (or microscopes!) is ridiculous. Other results became suspect if some are not true.

Census results should be given as honestly and as fully as possible. Only then can wildlife conservation understand what is happening to the resource and evaluate or modify management inputs accordingly.

1.3 TOTAL OR SAMPLE COUNTS?

Introduction

This is a controversial question. In general people with a lesser knowledge of statistics are intrinsically unhappy about a method which does not rely on sighting and counting each animal, but only a small proportion of them. In forest inventory and in most human population surveys only a proportion of the individuals are tallied - for reasons of both financial efficiency and the ability to use sampling statistics to estimate precision. The same factors hold true for wildlife counts as well.

What are total and sample counts?

A total count is one where the entire area of a reserve is searched and all animals seen are tallied. It does not follow that the entire number of animals is seen, although this is often assumed.

A sample count is one where a pre-determined portion of the reserve area is searched, usually in a number of small distinct sample areas. A "Sample" can be a large or small proportion of the area, the term:

Sampling Fraction is : $\frac{\text{area searched}}{\text{total area of reserve}}$

for example : $\frac{100 \text{ sq km}}{400 \text{ sq km}} = 0.25 \text{ or } 25\%$.

This is a measure of sampling intensity. Note that sample counts deal in densities, and data have to be extrapolated to the whole area of interest. This is the reason why sample design is so important; to ensure the sample units are representative of the total population. Note that "total counts" and "10% sample counts" mean that all the area was searched and that 10% of the area was counted respectively. It does not necessarily mean all the animals and 10% of the animals were counted, although sample and census design hopes that is so.

I. The problem with total counts:

Whilst it may be possible to count all the elephant in 10 sq km, or all the chital in 1 sq km, or all the jungle fowl in 10 ha, it is a much more difficult task to count all the elephant in 2000 sq km, as for example is attempted in Manas Tiger Reserve in Assam.

In general the larger the area to be searched or the smaller the animal, the more difficult it is to search that area effectively. Sometimes exceptional visibility can allow easy counting, for example the open short grasslands of 250 sq km Ngorongoro Crater in Africa are counted by observers with telescopes on the rim, each counting a geographically distinct area. This would be unusual in most parts of India, but has application in the steep and rocky alpine areas of the Himalayas (see section 2.4.6).

A large area requires a greater amount of time or a large number of people. These raise problems of under/over counting due to animal movement during the census, and to different observers recording (or ignoring) the same animal.

The greatest problem with a total count however, is not in the actual mechanics of counting but in the interpretation of results. There is no real way of telling how accurate or how precise the result is. You cannot give statistical confidence limits based on normal sampling statistics to an estimate from a total count. Even if a total count is repeated on three successive days and gives results of 960, 970, 980, you cannot tell if all animals are counted and counted once only - the same bias may occur throughout, and the real total could be 1050 animals. These particular data do indicate however that the method used in this instance is highly repeatable and that if in the future a similar count gave 892 animals, one could be justified in assuming a population decrease. Note that figures of 970, 900, and 1040, would not allow you to say there had been a decrease if you counted 890 next year!

What to do with successive total counts is a vexed question - do you take the highest or the average as the best count? If it really is a total count then the highest should be taken. If you think not all of the area was actually searched, and you can estimate how much was left out, then the data could be thought of as a sample count and the mean value chosen.

In some cases a series of total counts of an area could be used to calculate a best estimate by a bounded count or jack-

knife technique, see Appendix 5.2. A statistician should be consulted for this.

II The problem with sample counts:

Sample counts involve searching a smaller area, which automatically means less manpower, less expenditure and less disturbance to the system. These are distinct advantages.

Sample counts have the disadvantage of that the actual sample areas counted have to be known and measurable and discernible on the ground. So do all the very many census units for a total count based on block census. The choice of sample intensity and the location of sample areas are of importance in census design and planning, and there are a greater number of assumptions to be met in accepting sample census results.

In general the following assumptions have to be met in implementing sampling programmes:

- a) the objects to be sampled (animals) are distributed at random in the sampling space (the area of the reserve)
- b) the sighting of one object does not influence the chances of sighting another
- c) the conditions affecting observer - object encounter do not change during the operation.

Of these, the first is perhaps the most important and is discussed more fully in the next section. The second is true for solitary animals, but only becomes true for gregarious animals if the herd is taken as the sample object. The third may be taken as met if the whole operation is undertaken in one ecologically homogenous time period i.e. the late dry season, or winter or post rains etc. Animal reaction to observers should not change during the operation, i.e. by becoming habituated, or wilder, due to disturbance.

The use of sampling statistics in planning a census:

[The readers are advised to read the appendices on statistical terminology (5.1) and on calculating variability (5.2).

If animals are distributed uniformly, as for example trees are uniform in a plantation, then each same sized sample would have the same number of individuals; e.g. in every 0.1 ha there may be 50 trees, and there would be no variation between samples. Large animals are not distributed uniformly, but may be considered to be randomly distributed if in a homogenous environment. If a single 1 sq. km. sample was looked at there may be 0 or 10 animals in it, i.e. there would be greater variability. Sampling statistics are about understanding and using variability. If a sample count showed 50 animals this year and 100 next year, would you be justified

in assuming a doubling in total population size? No, not unless you had some prior knowledge of variability and sample intensity.

If a series of counts of equal area of 1 sq. km. give 2,4,6,8,10 animals, the mean number is 6. Another series may give 4,5,6,7,8 animals, again with a mean of 6. The two systems differ in their variability about the mean, where the mean would be the estimate of the actual number of animals in that 1 sq. km., i.e. 6. However our confidence interval about the mean would be different in each case.

Note that if a large number of samples are taken then one will be more confident that the estimated mean density is close to the actual true density, but if the sample size is small, then one would be less confident of the mean. The word "precision" in sampling deals with the variability of the system and sample size. A "precise estimate" is one that would be found again if the exercise were repeated. This could be for example, because there is little natural variation, i.e. most square kilometers of forest have 5, or 6, or 7 animals in them; or, because a very large number of samples has been taken. Accuracy however deals with the level of error in the method. A method may be very precise but inaccurate, due for example to inability to see calves of rhinoceros in tall grass. When accuracy suffers from a known and consistent bias, then the estimate can be corrected by a suitable correction factor.

Conclusions

Total counts have greater acceptance by laymen, but in most cases are difficult to undertake, and are inefficient in use of resources. They have greater levels of disturbance. Total counts do not have confidence limits allowing the testing of significance between successive counts.

Sample counts are less convincing to a layman, but can give biologically and economically more efficient results than a total count. Sample counts need greater efforts in design and planning to ensure statistical assumptions are met, but can give a greater quantity of usable information.

1.4 THE PROBLEM OF ENSURING REPRESENTATIVE SAMPLES AND THE USE OF STRATIFICATION

Background

The previous section stated that sample counts required the assumption of animal groups being distributed at random within the census area. In most cases, for large protected areas, this is not true. Protected areas have several habitats, and wildlife species will have different ecological adaptations and habitat requirements. Each species will not be

distributed equally throughout the area but will prefer some habitats and avoid others. They are thus not distributed at random.

Non-Random Distributions

Non-random distributions are common place in nature. In the severe dry season most animals which are at all water dependent will congregate near waterholes or in areas of more palatable forage. Many animals have higher densities near habitat edges or ecotones; chital around the periphery of meadows in sal forest in Kanha form a good example. Roadside in many protected areas are purposefully cut back as fire breaks and view lines. Regenerating vegetation attracts many animals such as chital, boar, gaur, which may have significantly higher densities along roadside than elsewhere. This is obvious in many parks and sanctuaries in India.

If a census operation used such a road system for transect counts of say chital, what would happen? A density would be obtained from animals seen on periodically cut roadside verges, and this is going to be very much higher than the overall density of chital in that forest block. The census would greatly over-estimate animal abundance. It would have a high positive bias.

In many cases roads avoid steep terrain, they may be placed in valleys which naturally have higher wildlife densities. In some protected areas, artificial waterholes and salticks have been constructed near roads, again attracting higher than normal densities of animals. The opposite can be true, with animals avoiding areas near busy roads, especially with foot traffic. Dust and diesel fumes can also reduce palatability of roadside vegetation.

The answer has got to be, “do not use existing tracks for detailed density information”. Use them for comparing seasonal or annual changes, use them for indices of abundance, but NOT for density for the whole area. Roads can be especially created for census operations, with a random or systematic grid of tracks, with no roadside disturbance and no visitor traffic. Otherwise transects will have to be along foot paths or walking across country to ensure a representative sample.

Where the distribution pattern is naturally non-random then different techniques can be used. Firstly the non-randomness may be seasonal, as for example congregating by water in the dry season, but being widely dispersed after the rains which may be the best time to undertake the count. Where there are still distinct distribution differences, then stratification must be used.

Stratification

Stratification means zoning. The study area is split into zones, which are counted and analysed separately. Zones may be based on habitat factors such as vegetation type, terrain etc., or management factors, such as core and buffer areas etc. Whilst there may be an obvious difference between chital density in sal forest and on meadows, one assumes that within each of these separate habitats, distribution is not significantly different from random.

The purpose of stratification is to reduce variability in the data set and hence increase the precision by lowering confidence limits around the estimated mean. An example may make this clear. Suppose there are ten 10 km transects across a 200 sq. km. protected area, five are in sal and five are in an open *Acacia-Zizyphus* scrub. The following numbers of chital are seen per square kilometre :

Transect Number	Chital Density per sq. km.	Density Data overall	Stratified Densities
1)	5	) 7.4 per sq. km.) $\pm$ S.D. of 3.95) Which is a) coefficient of) variation of 53%) and a standard) error of ± 1.25) which gives) confidence limits) of ± 2.75)	) 4.2 ± 1.92) CV = 45%) Confidence) limits are) ± 1.03 .
2)	2		
3) Sal	7		
4)	3		
5)	4		
6)	8	) 10.6 ± 2.4) CV = 23%) Confidence) limits are) ± 2.4	
7)	12		
8) Scrub	9		
9)	10		
10)	14		

If the protected area has a total area of 200 sq km of which half is sal and half is scrub, then total population estimates with confidence intervals are :

Unstratified

Stratified

Sal

Scrub

$7.4 \pm 2.75 \times 200 = 1480 \pm 550$

$4.2 \pm 1.03 \times 100 = 420 \pm 103$

$1.06 \pm 2.4 \times 100 = 1060 \pm 240$

) which overall is 1480 ± 343 .

There is thus a considerable saving in precision, 343 is much less than 550.

Stratification also allows you to place sampling effort most efficiently. And remember that counting does take time and money, efficiency is important. Rules of sampling procedures suggest you put more effort (more samples) into areas where densities are greatest or inherent variation is greatest, and less effort (fewer samples) where densities and variation are lower.

Census Operations

2.1 SIMPLE INDICES OF POPULATION ABUNDANCE

General

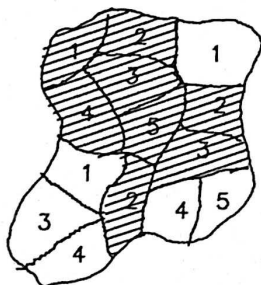
An earlier section suggested that managers are primarily interested in two aspects of census. Trends of population change (are they increasing, decreasing or showing no significant change?), and knowing population response to management inputs (are there more or less on burnt or unburnt areas, areas weeded or with weeds, or where cattle have been removed or water holes put in etc.?). This information may be more useful than knowing absolute numbers of animals in a given area.

We have also stated many animal species are difficult to census *directly* by counting actual animals, as they are rare, shy, camouflaged or nocturnal. However in many cases animals give signs of their presence in characteristic spoor, dung or calls. Counting such signs or indirect *evidences* of an animal's presence gives indices of population abundance useful in management situations.

The best indices are those which increase linearly as numbers increase, e.g. spoor and probably dung. Calls may follow a curved response to population growth, as may nests etc.

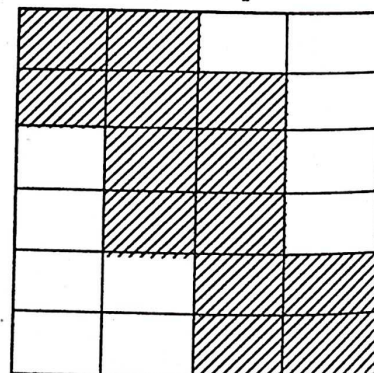
We discuss several possible methodologies for use in Indian conditions - the interested wildlife manager will no doubt be able to develop many more, or modify these methods to suit his particular circumstance.

Remember to think out the assumptions behind the method you choose. If you count the number of trees dam-



Swamp Deer Distribution by Compartment in a Forest Range of 3 Blocks (fictitious example)

OR where no easy compartment boundaries exist, a simple grid may be prepared as shown here.



Hog Deer Distribution by 2 km x 2 km grid square (fictitious example)

aged by porcupine in one area and compare it with data from another area, can you be sure differences are due to porcupine number? Perhaps differences are due to changed food preferences; the second area may offer more succulent roots or tubers and so have less bark damage!

2.1.1 Presence/Absence and Qualitative Mapping of Abundance

Introduction:

The statement that "Ranthambhore has sloth bear, Sariska has none" - already tells you definite facts about sloth bear populations in Rajasthan. The statement that "in Sariska, caracal have been sighted in Sariska and Thana Ranges but not in the others" gives a greater level of information on this species. One would have more confidence in the statement if it was qualified by, e.g.: "_____ and staff have been specifically on the look-out for caracal for the past two years."

For the rarer species, or for small units of land, the simple statement of absence or presence gives useful data on patterns of abundance. When done systematically the recording of presence/absence data can yield valuable results. Note that this has not yet been done for most wildlife species in India.

A Survey by Forest Management Units or Grid Squares:

Within a protected area, it is often possible to plot the distribution of a species by recording its presence or absence in each compartment of each block in each range. An example of such a survey (which can be done by questioning beat officers) could be as follows, for say swamp deer:

Qualitative Measures of Abundance:

Simple presence information can often be extended, by for example, giving estimates of relative abundance such as “rare, occasional, common, plentiful”. Care must be taken in describing these terms for each species. Seeing three rhino in a compartment might make you say they are common, seeing three chital may be thought of as rare or occasional.

Such qualitative abundance estimates can also be mapped, eg:

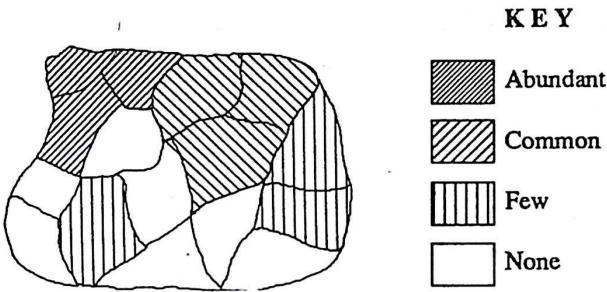
Note: Evidence such as dung may be used in building up such pictures of distribution and abundance.

Some Mathematics

Caughley (1979) describes a quantitative census technique based on presence/absence frequency in small areas.

When survey blocks are small then the frequency of occurrence of the animal in the block can be used as quantitative index of abundance using probabilities of presence.

Using Shading



or Using Numbers in Grid

4	4	3	1
4	4	3	2
3	3	2	2
3	2	0	0
1	1	0	0
1	0	0	0

OR

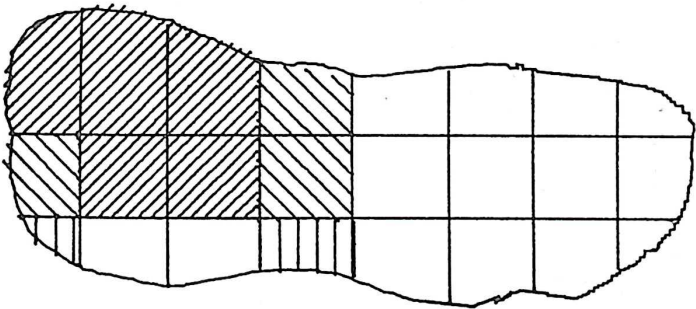
4. Abundant 3. Common 2. Some 1. Rare 0. None

Note that descriptive words such as ‘few’ or ‘common’ etc. must be defined for each species in each area.

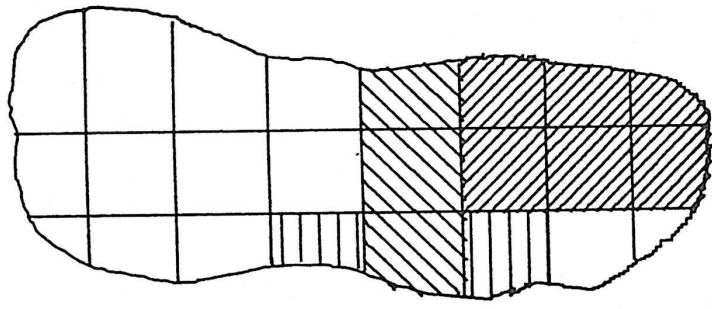
Seasonal Change in Abundance:

If such estimates can be made at different seasons then information on seasonal patterns of abundance can be given, eg:-

Note that if the block becomes too big then the probability of occurrence becomes 100% or 1.0 (Probabilities are best given as fractions). For example, what is the probability of finding a tiger in 1 sq km of Kanha N.P.? There is obviously a chance,



MID-MONSOON



MID-SUMMER

Distribution of Chital in a Protected Area.

Caution:

These maps indicate estimates of relative animal abundance. It is important to check that they do not become maps of searching effort. Each square or compartment should be searched equally thoroughly, or each beat officer should be questioned and information followed up by the same person. There is great scope for observer bias, and care must be taken in checking bias and in not giving too high a degree of confidence in results. They indicate patterns, not absolutes.

let us say 20% or 0.2. But if we are to ask of the probability of finding a tiger in 100 sq. km., the probability is 100%.

The Probability of a survey block containing an animal is:

$$P = \frac{n}{s} \quad \begin{array}{l} n = \text{number of blocks with an animal} \\ s = \text{number of blocks sampled.} \end{array}$$

The Variance of P (by which you can tell if the probability is different from year to year) is given by

$$V(P) = \frac{Pq}{s-1} \quad (\text{where } q = 1 - P)$$

For example, if you survey 100 blocks and 60 have presence of the rare species then:

$$P = \frac{60}{100} = 0.6$$

$$\text{and } V(P) = \frac{(0.6 \times 0.4)}{99} = 0.0024$$

This means that the real probability P lies between

$$0.6 \pm 0.0024$$

Another survey the following year, when 51 out of 80 blocks had the animal gives a value of:

$$P = \frac{51}{80} = 0.638 \text{ and } V(P) = 0.0029$$

The two values of P can thus be taken as significantly different.

2.1.2 Road Side Index for Monitoring Population Trends

Introduction:

It is frequently stated that for nearly all management purposes information on population changes is required rather than actual numbers. Trends are easier to monitor than absolute numbers and require less statistical and sampling formality for interpretation. This section describes a simple technique for collecting systematic data on animal presence which can be analysed to give population trends. This is often called monitoring a population.

The Basic Data Unit:

What is needed is the collection of specific statements of animal presence, which can be located in time and space. When summed and averaged over a time interval, these statements give a mean value of animal presence which can be compared with other time intervals, (eg. last year) or other areas. For example "Driving from Dhikala to Paterpani in Corbett National Park (11 km) on 2/2/86 from 6-7 a.m., I saw 27 chital and 4 sambar", is a specific data statement and it is repeatable. This could be further elaborated as "This was repeated five times in February and the average count was 34 chital (range 19-48) and 6 sambar (range 1-11)".

"In April 1985 I saw 30 wild boar in Dudhwa" is not repeatable, as the effort, how much distance, and time and

place (where in Dudhwa) are not known. The reader cannot tell if the observer spent 30 days in Dudhwa and saw the same animal each time, or if 30 animals were seen at one time.

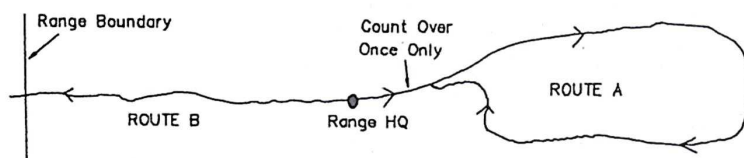
Methodology:

This method is designed for surveys along tracks and roads, and can be used for walking/cycle patrols along trails, vehicles along roads etc.

Within the study area a number of tracks which can be covered regularly, and which include representative areas of all habitats, are chosen for monitoring. A distance coverable in 2 hours or so is the maximum to be chosen, e.g. 30 km, by vehicle.

A decision is taken to cover this network a number of times per time interval, e.g. 5 times per month, when monitoring is undertaken. These travels can be undertaken in conjunction with other duties, but during travel itself, observation has priority, e.g. slow speed (20 km per hr) and the use of regular observers. Such travels are best done in the morning.

Example of a Monitoring Network of Motorable Tracks in a Wildlife Range:



The track is split into kilometre segments using the vehicle mileometer or marks on trees. Animals are carefully searched for. Sightings can be entered on a proforma as:

Animal Monitoring			Date		Recorder		
From	To		Time out			Time in	
No.	Km.	Sp.	No.	M	F	IMM	Notes
1	2-3	Chital	27				Eating ber fruit. 1 F in poor condition etc.
2	4-5	Nilgai	8	0	5	3	
3	4-5	Boar	6	-	-	-	

etc.

On the reverse of the proforma, trip totals can be summarised e.g.

Species	No. of Obs	Total
Nilgai	3	29
Chital	11	77

etc.

It must be emphasised that each trip acts as one sample, and consecutive samples may differ greatly from each other.

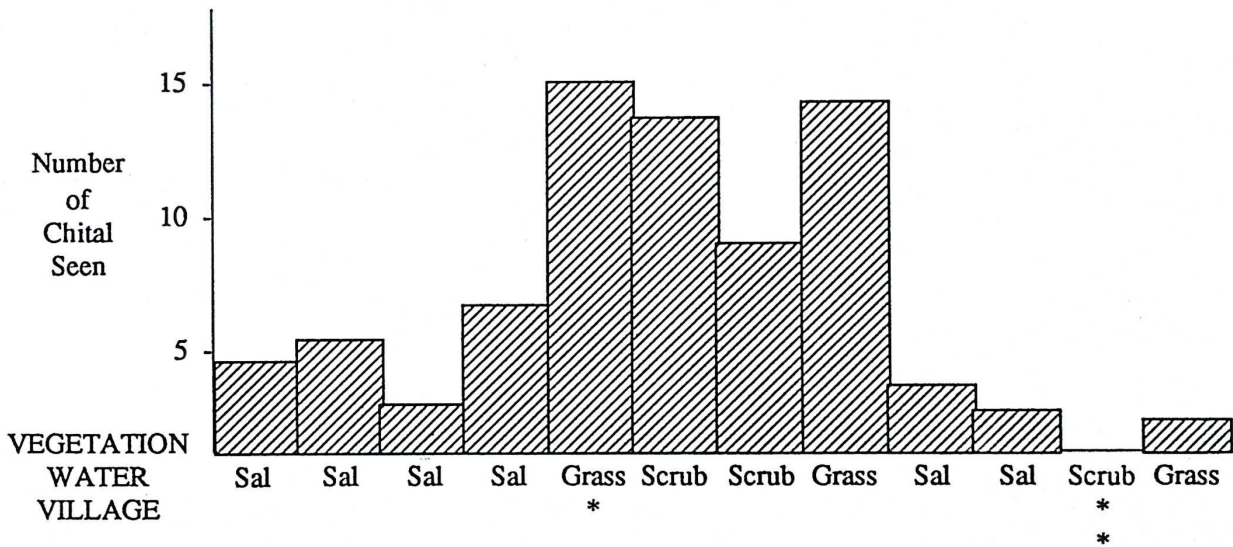
Data are therefore best presented as averages. For each census time interval (e.g. one month) the mean and range of sighting totals can be given, for example:

Month May 1984 Sariska to Kaligati Morning Counts 5-counts			
Date	Nilgai	Sambar	Chital
12-5-84	14	4	72
14-5-84	29	9	64
etc.			
Total	125	60	290
Mean	25	12	58
Range	14-38	0-21	36-91

With data sets of 5 or more samples per time interval, it is useful to give confidence limits to the mean value so as to detect significant changes (See section on statistics, in appendices 5.1, 5.2).

How many trips should be made per time interval? This depends on the variation in the distribution of animals in the study area. If consecutive daily counts are very different, then several trips (over 5) should be made. Again, how precise do you want the data to be? If you hope to pick-up annual changes of say 10-15% in population size, then a very large number, may be 15 trips, will be required. This need not be done every month. Large data sets could be collected once a year, other months being used for data showing change in seasonal distribution.

The kilometer grid mentioned earlier is useful for correlating animal sightings with habitat features - e.g. vegetation, water, disturbance. Segments with a consistently higher or lower number of animals than the average can be examined in detail to determine important habitat factors. This however is beyond the scope of this manual on census techniques, but a diagram is used to illustrate possibilities.



Notes. This method is frequently used for monitoring bird populations, e.g. Kalpavriksh (a non-governmental environmental organisation) in Delhi have counted birds seen over the same set route in several areas over the past eight years.

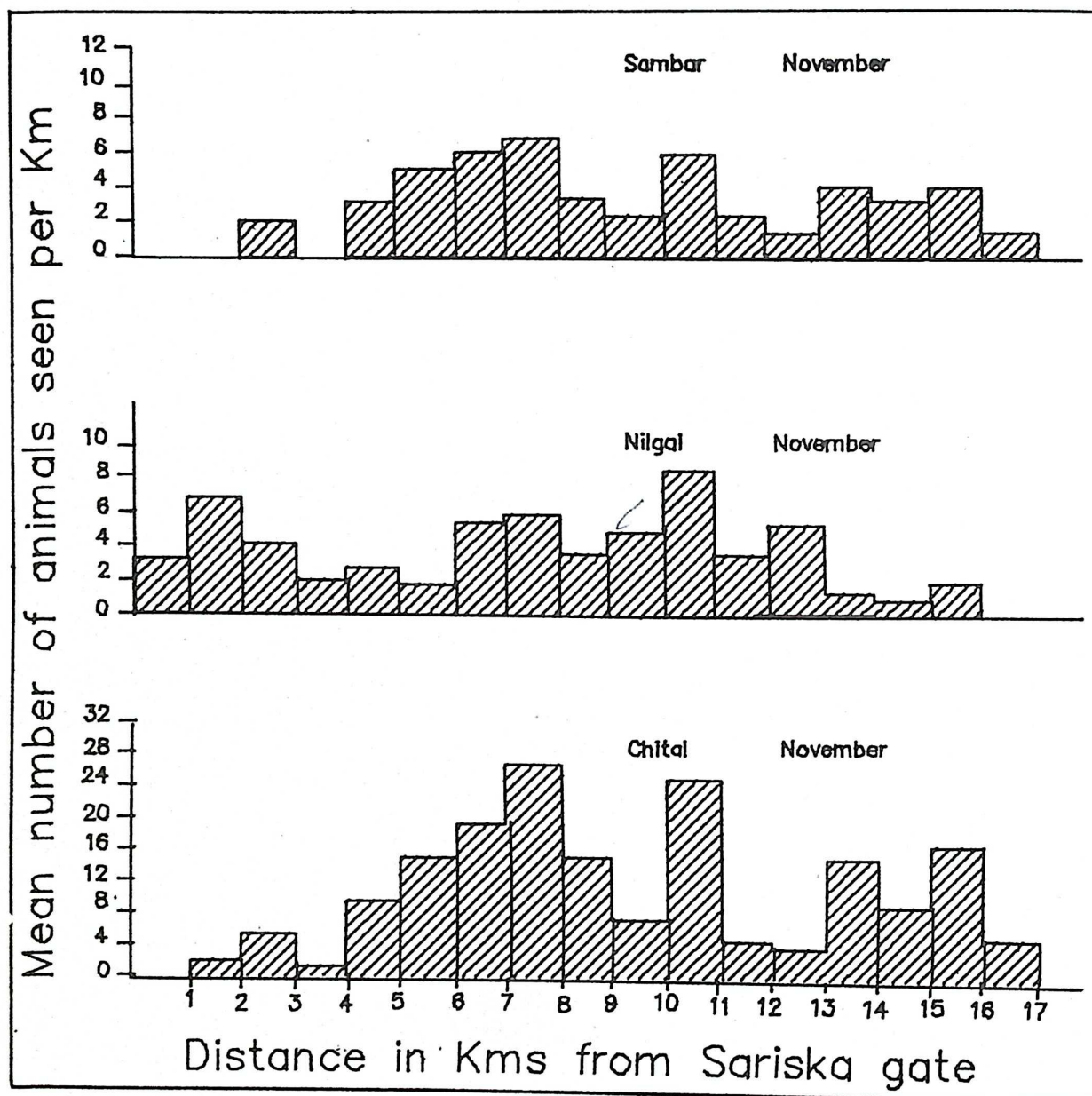
Box 1

Field Example: Roadside Monitoring

Sariska Tiger Reserve

Patterns of abundance and distribution are displayed for three common ungulates in the main valley of Sariska Tiger Reserve. Data are given for the post monsoon period - November.

Data come from several coverages of the 17 km road transect either in the early morning or in the late evening for each time period. Animal sightings were noted within separate 1 km long segments.



2.1.3 Dung Surveys

Introduction:

Dung is a reliable indicator of animal presence (provided one can identify the species!) and has frequently been used for estimating abundance. In certain situations dung counts can lead to actual population estimates, but there are many assumptions to be met, and this technique may not be easy to implement in the tropics (see a later section 2.2.2). However dung counts can more easily be used as an index of population abundance. If at time 1 there is an estimate of 120 dropping per ha and at time 2 there is an estimate of 240 per ha, the inference is made that the population size has doubled. (Theoretically population size could remain unchanged and defaecation rate could double. But this is assumed not to take place!)

How then to collect data on dung density distribution?

Field Methods:

i) The first criterion is the correct identification of dung from different species, and the second is the recognition and separation of different groups of dropping.

Superficially the individual pellets of sambar, nilgai and chital dung are similar. Chital are smaller of course, but there are large chital and young sambar! Nilgai frequently make use of lavatory sites and dung is deposited on large heaps. But this may not always happen. A large heap is definitely nilgai, but single individual group of pellets may also be nilgai, and could be confused with sambar. Sheep and goat pellets overlap with chital, and camel may overlap with nilgai.

Differences are in size, shape (roundness or elongation) and pattern of indentations or protuberances at the ends of each pellet. The best way to ensure accurate dung identification is to keep a selection of pellets of each species in transparent bags in your pocket. These pellets should be collected when you see an animal defaecating. Try and take pellets from male, female and immature animals. Use these as a reference for comparisons in the field. Note that a single pellet may be aberrant, always look at the whole group when identifying species. Seek the help of experienced local people. Stimulate discussion, ask several people, and ask for their reasons for discrimination between species.

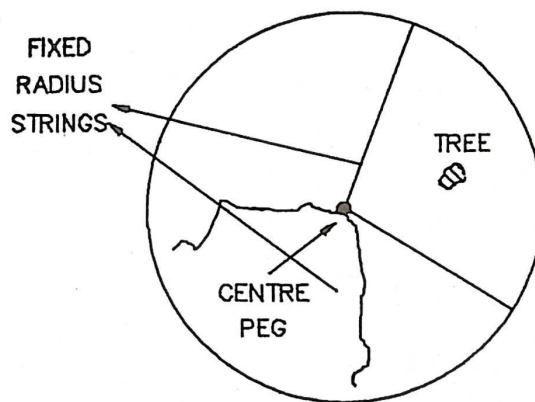
Separation of different groups is based on thought and experience. Usually dung is deposited at one spot, but a moving animal may deposit dung over a few metres. If size, shape, colour or apparent age of droppings differ, then assume they are from different animals. If there has been recent rain, surface wash may have moved pellets down slope. Cold dry seasons when there is reduced insect and weather breakdown of dung are best for dung surveys.

ii) How carefully does one search for dung? We have done

field trials where very careful and slow searching, involving turning over all leaves and examining the litter, does give a much greater number of pellet groups than a more rapid surface search. However we are dealing with indices of relative abundance not absolutes. Provided the level of searching intensity does not change during surveys, the intensity itself does not really matter. Care should be taken that the system does not change during the survey, for example leaf litter fall, which would mask much of the dung.

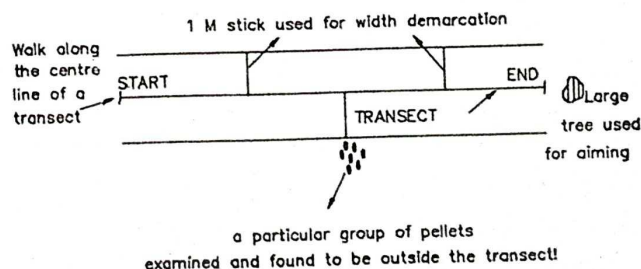
iii) Sample plots should be designed to allow easy searching. Plots that are too large take an excessive time to cover, and portions may be missed out. Plots that are too small are inefficient in that several of them will have no dung and yet time is taken up locating and setting up plots.

Quadrats are time consuming, especially squares or rectangles, when setting out exact right angles at the corners is difficult. A circular plot using a central peg and fixed radius string is easier to use. If several strings are attached to a central peg, then it is easier to move around obstacles, e.g.



Example of a simple circular sample plot. (e.g. 2.0 m)

I prefer transect samples, in that they are easily extended to cover a larger area, they run across micro-habitat diversity (e.g. shade, non-shade; thicket clumps and openings; small scale topography etc.) whereas quadrats have to be placed in a small location, and this is often subject to observer bias, e.g. avoiding *Lantana* or thorn thickets. We use 25m transect lines, with a 2m width (30 paces is approximately 25m). Width is determined by using a 1m stick from the centre of the walked census line e.g.

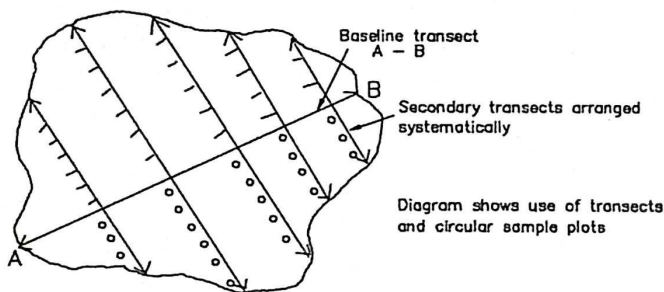


Transects or quadrats should be large enough to allow most samples (over 60%) to have 1 or 2 dung groups at least. With low density populations, transects may have to be 50 or 100m long. For elephant, transect width could be doubled (or in open country quadrupled) as droppings are easy to locate.

Sample Design:

The accurate definition of objectives is important. Let us take the simple case of comparing use of two adjacent habitat types, e.g. *Zizyphus-Butea* grassland in valleys and adjacent *Anogeissus pendula* woodland on slopes, a typical feature of Sariska Tiger Reserve. The goal should be clear - is it to compare just two specific localities, or all patches of *Zizyphus* and all patches of *Anogeissus* in Sariska? If the latter then an adequate proportion of such patches should be selected from the whole protected area. Use sampling design considerations, see appendix 5.1.

The whole habitat unit should be searched, not just edges. Base line transects should run across the whole area e.g.



1. Baseline transect A—B
2. Secondary transects arranged systematically

Diagram shows use of transects and circular sample plots

The diagram shows a number of samples (transects and quadrats) placed along second order transects which systematically cover the whole area of interest.

Note that the sample area should be homogenous, and so we should expect secondary transects to have similar mean dung densities. The same may not be true for individual samples. Samples near a stream or near habitat edges may have significantly different densities. Major transects should cut across such zonation. Each individual sample should be totally within one homogenous zone i.e. a 25m x 2m sample should not cover two major habitats.

In practice we have used a sampling grid of sample points spaced every 50m along a transect, and these transects themselves being 200m apart along a baseline. Ten transects with 5 points may give an adequate sample size for each locality.

Data Recording:

Each second order transect will be recorded separately on a proforma, possibly by a different census team. Two people per sample transect works well, one to walk, search and call out sightings, the other following, recording data on the proforma, e.g.

TRANSECT A, Kalighati area, 22-10-86. Obs. H. Patel.

Sample Transect	Nilgai	Sambar	Cheetal	Other	Habitat
1	11 2	1 1	111 3	Boar 1,	Flat, open
2	111 3	O	1 1	NIL	Flat, tall grass
3	O	11 2	11111 5	NIL	Flat, open

etc.

More detailed habitat notes can be put on the back of the proforma.

Data Analysis:

Total for each transect should be calculated from all data.

Transect	Number of sample points	Nilgai	Sambar	Cheetal	Boar
A	6	6	3	12	3
B	6	9	4	10	0
C	6	4	1	14	1

etc.

Mean Values 8.2 3.1 13.6 1.9

Standard Error 1.0 0.6 2.0 0.2

Convert the data to density per hectare (or other standard area measure).

If 6 separate 2m x 25m samples were used for each transect then the area searched is 6 x 2 x 25m = 300 sq m.

Dung Density per hectare then becomes

Density/ha 273.3 103.3 453.3 63.3 groups/ha

Standard Error 34.0 21.0 65.0 6.7

as: $8.2 \text{ in } 300\text{m}^2 = \frac{8.2}{300} \times 10,000 = 273.3 \text{ groups per ha.}$

Valid Comparison:

i) Can one compare chital and sambar occupancy of *Zizyphus* from their dung? Does knowing chital have 453 and sambar 103 dung groups per hectare have any value?

The strict answer unfortunately is NO, all we can talk about is dung, not animals, as we do not know defaecation

rates. If chital produce 4 times as many groups of pellets per day as sambar (which could mean fewer pellets per more frequent defaecation) then there would be more sambar than chital in the area!

Note nilgai are difficult to compare as they have different defaecation habits, using lavatory sites, where detection of individual groups of pellets is virtually impossible.

Data do indicate trends however, especially if dung densities are very different, one could infer differential use.

ii) Can one redo the count next year and compare sambar figures from 1986 to 1987? Assume next year there are 168 per hectare. Can one assume an increase? ONLY if you can assume similar conditions, i.e. rainfall timing and intensity, which may have broken up dung two weeks before the 1986 survey, but there may have been no rain for ten weeks in 1987!

Choose similar conditions and methods at a time of year when environmental parameters will have little effect.

iii) Can one compare chital in *Zizyphus* and *Anogeissus*? Assume there are 453 per ha in *Zizyphus* and 204 in *Anogeissus*. YES provided you can assume defaecation patterns are the same in both habitats. Observations on red deer suggest they have different rates of defaecation during feeding and resting periods. If they feed in *Zizyphus* and rest in *Anogeissus* in shade, then comparisons may not be valid!

Box 2
Faecal Pellet Analysis to
Determine Herbivore Relative
Abundance in Three Habitat Types
(Sariska, November 1986)

Data in Density of Pellet Groups/ha.

Species	<i>Zizyphus</i> Valley	<i>Anogeissus</i> Slopes	<i>Boswellia</i> Ridges
Nilgai	114	19	21
Sambar	1678	2994	3479
Chital	2967	2338	656
Sample Points	51	24	20

Each point consists of two 25m x 2m transects.

Note Low density for nilgai as a pellet group is a large lavatory site. Nilgai dung is more abundant in the valley.

Chital have much less dung on the rocky ridges whereas sambar dung density is highest there.

2.1.4 Waterhole Technique for Wildlife Census

Introduction:

A census technique where large animals are counted from a hide as they visit waterholes, is in widespread use in the drier parts of India, e.g. Sariska, Ranthambhore, Gir, Melghat, Tadoba. The technique is used where all dry season water sources are known, when such sources are not too numerous and where water sources are distinct localities widely scattered in the census area, not long meandering streams or rivers. The method does have value as an index count, but the large number of untested assumptions means that there is no validity for its use to estimate actual population size.

Assumptions:

Basic assumptions to use the method as an index are as follows:

- That there is a linear relationship for each animal species between the number of animals seen drinking per time period and the number of animals in the area.
- That field staff are able to record an unbiased estimate of animal numbers drinking at a waterhole; i.e. staff remain awake, are literate and that their presence in a hide does not deter animals from drinking.

Assumption 'a' probably is true although the relationship may not be simple and will differ from species to species and between age and sex classes, and probably will not be the simple "each animal drinks once per 24 hours".

Assumption 'b' can be made true by effective project design. We do know of cases, however, where project staff have fallen asleep, where census staff were illiterate and guessed numbers seen, where hides have been built on top of waterholes giving a real noise and smell deterrent, and where staff have lit fires, made tea, drunk alcohol and cooked at the base of the hide. In some cases less than a 24 hour period was used to approximate a 24 hour period: e.g. 2 pm to 10 am, e.g. 9 am to 7 am the next day, with an untested assumption that "few animals drink in the missing hours".

For attempts to estimate actual animal numbers, a further assumption is necessary - that the frequency with which an animal drinks is known. In India many people use the unfounded assumption that animals drink once per 24 hours. There is NO biological basis for this fact. Cervidae with less heat tolerance and water conservation adaptations than Bovidae almost certainly have different drinking regimes. Immatured and lactating females will have different requirements from males. Cloudcover, humidity etc., will affect water requirement, as will the availability of green forage with its own high water content. If the exact frequency of

drinking by the study population at that ecological time period is NOT known, then there is NO justification in attempts to estimate total population size. Frequency could be obtained from observing marked animals, but that is outside the scope of this section.

A survey in Madras Zoological Gardens showed chital drank three times more frequently than nilgai.

Methodology:

1) The survey should be undertaken at the time of year with the least availability of water. This will often be in mid-late May.

2) A prior survey should locate all water sources in the entire census area. Simple access to the water points should be opened and a machan/hide constructed.

3) Machan construction should be for at least two people and whilst allowing for adequate visibility should be far enough away from the water that animals are not deterred from using the water sources. Machans should be complete a few days before the census period.

4) A census period during full moon should be chosen.

5) Field staff should be selected well in advance, using one experienced literate person plus one helper for each machan. Staff should check their machan suitability before the census operations.

6) Staff should be trained in methodology and in using the proforma, by a trial run sitting at a waterhole for a few hours, and they should be aware of the objective and importance of the census. They should take food, water, clothes etc. with them for the full census period. Binoculars should be issued at the most important waterholes. All staff should have wrist-watches.

7) Census should start in the evening of day one, with staff having rested (hopefully sleeping) during the day. Data collection should start an hour after arrival in the machan, to eliminate the disturbance period. An evening start gives staff a better chance of staying awake during the night period. A cheap alarm clock continually being set for an hour ahead (and placed in a muffled blanket) reduces the risk of long sleeping periods. The census should continue for a full 24 hours after data collection began.

8) A suggested proforma is given below. The most important columns are species and total numbers seen. It is not realistic to expect staff without binoculars to accurately determine sex and age classes, or even to do such sexing at night with binoculars!

9) After the census is over, forms from all waterholes are

collected at range offices and checked by the range officer and forwarded to the census co-ordinator who will compile species totals.

Interpreting Results:

What do the results mean? The result is an index of animal presence. A large population will have more animals drinking than a small population. If populations increase in size, then the number of animals seen drinking will increase. Data from successive years can be compared to show trends in population size, provided conditions remain constant!

A study¹ in Kruger N.P., South Africa, illustrates the problem of trying to estimate actual number. Animal numbers are well known in Kruger from aerial and ground survey.

Species	Actual Relative Abundance in Kruger	Relative Abundance at Waterholes
Impala	70.7%	18.4%
Zebra	9.0%	34.7%
Wildebeest	8.1%	21.4%
Elephant	4.1%	1.9%

The pattern of animal presence at water is very different from the actual density.

It is useful to know how consistent a figure can be obtained for animals seen drinking at each census period. If a first count gives 282 nilgai and a second count two days later gives 171 or 369 then the method has little value and a figure of 380 the next year could *not* be used to indicate a population increase. Repeating counts a few times in one time period can give an indication of consistency or repeatability. It may not be realistic to expect managers to mobilise staff to recount every waterhole two or three times in a week. But a proportion of waterholes should be repeatedly counted. Either choose waterholes with large numbers of animals or choose a group of adjacent holes and count each three times. Use the mean figure and lower and upper limits to indicate the range of expected values for the whole area in that year.

- e.g. 1) from an initial total count of 52 waterholes, 520 nilgai were seen.
- 2) two or three repeat counts of 10 waterholes gave 120 & 168 nilgai and 146 in the 10 holes from first count.
- 3) mean count value is 145 nilgai for these ten sample waterholes, with a lower level 25 or 17% below, and a higher level 23 or 16% above.
- 4) this will give a range of census values of 432 and 603 around the total 520.

¹Young, E. 1972 The value of waterholes in estimating wild animal populations. *Journal of Wildlife Management Association of South Africa*. 2(1) 22-23

Proforma for Waterhole Census

Range _____

Block _____

Waterhole _____

Name of Observer _____

Date _____

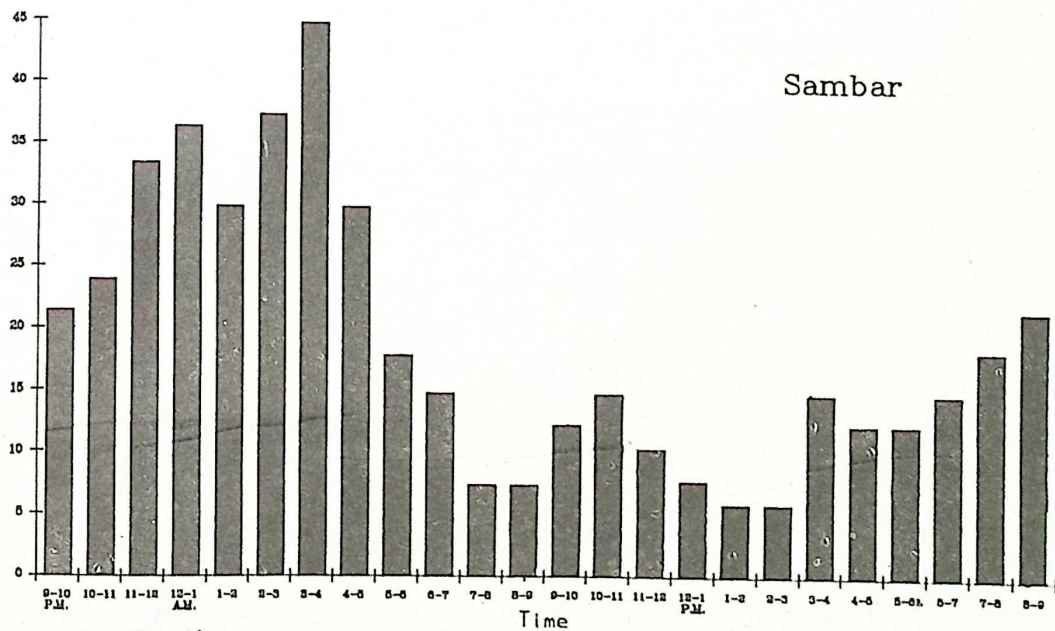
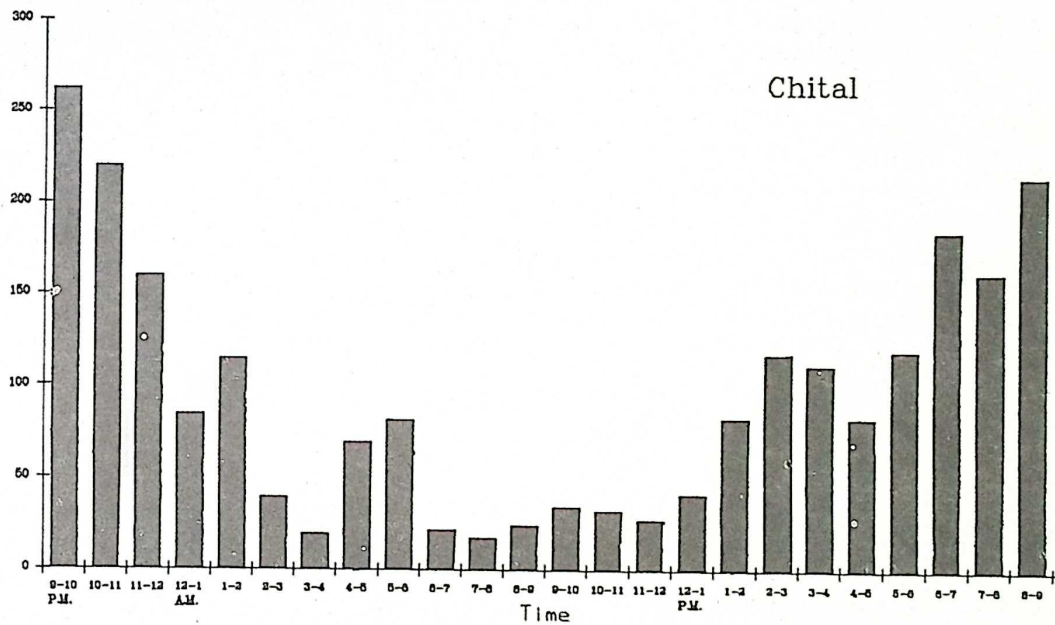
Time started _____

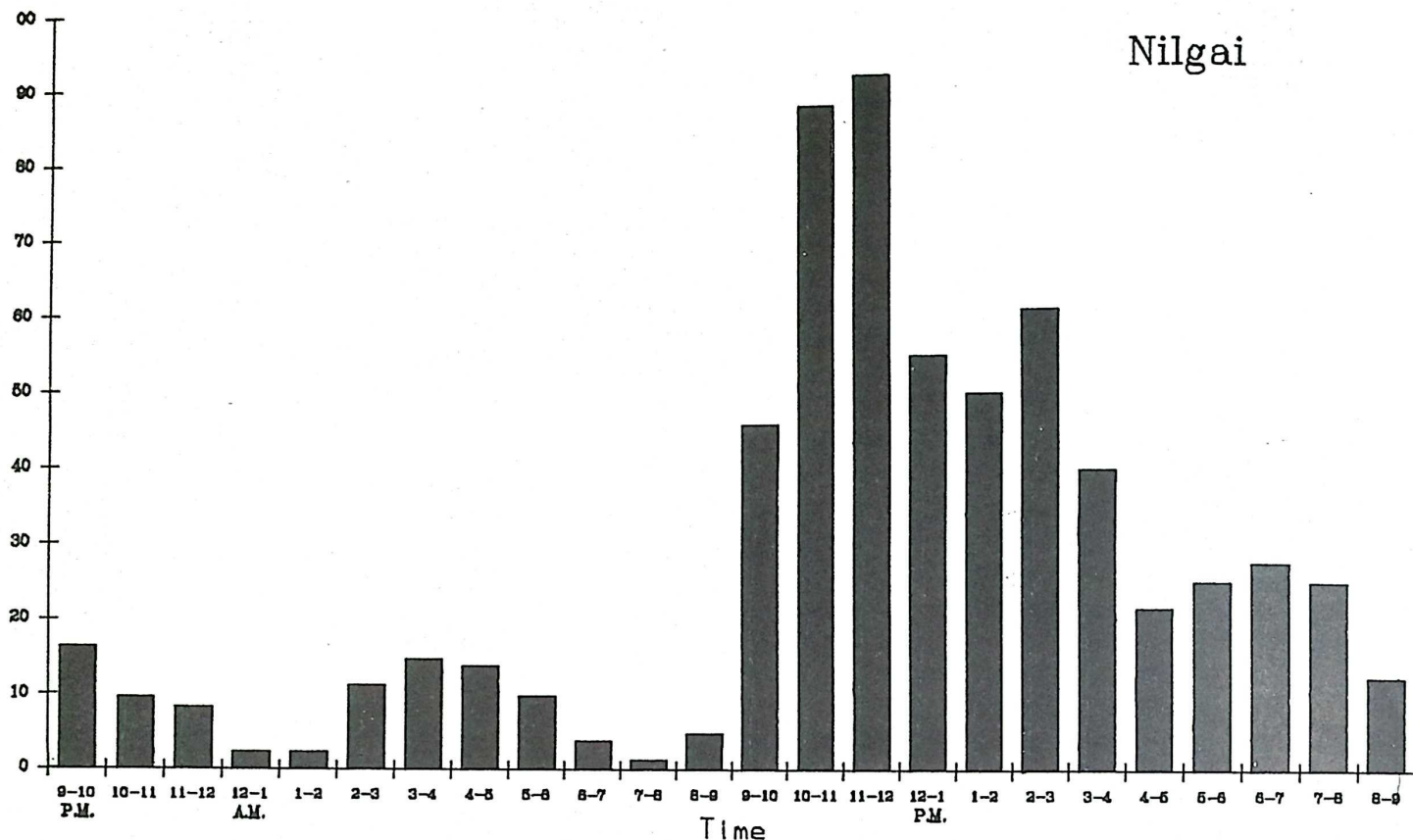
Time finished _____

Signature of R.O. _____

Sl. No.	Time	Species	Number	Adult Male	Adult Female	Immatures	Others
1	5.35 pm	Chital	2				
2	5.50 "	Sambar	7				
3	6.50 "	Langur	29				
	etc.....						

Note: The following diagram portrays the pattern of time of drinking for different animal species, and stresses the importance of a full 24 hour count (data from V.B. Mathur, pers. comm., 1989).





Box 3 Waterhole counts in Tadoba National Park, Maharashtra

An interesting paper on the use of waterhole counts in India is : R. Choudhary, 1987 Methodology for population estimates of herbivores: a statistical approach in Indian conditions. Tiger paper 14(3): 11-17. The paper presents a detailed methodology and census data. One point is highly questionable, and that is the assertion that a six hour period (1600 hrs to 2200 hrs) is adequate to count all animals coming to water! Detailed observations in 1989 showed animals drinking at all periods throughout a 24 hour day and that different species had different peak periods (V.B. Mathur, see diagram). A six hour period will give another form of relative abundance estimate, but can not be used to estimate absolute number.

The paper shows animal numbers over 3 consecutive years.

	1984	1985	1986
Gaur	218	93	202
Chital	1246	1027	1602
Sambar	133	182	256

1985 low numbers are explained by disturbance due to bamboo working. Tadoba is adjacent to the extensive Andheri Wildlife Sanctuary and animals move from one to the other. Ideally censuses should cover a complete ecological unit.

Within the one year however, repeated counts at waterholes showed considerable variation, but this may have been confused in adequate timings.

2.1.5 The Use of Calls for Bird and Other Species Census

Introduction:

Sounds indicate the presence of a species in a locality, but the opposite is not true, no sound does not necessarily mean no animal. It is obvious then that any use of sounds, calls, roars etc. must be done very cautiously. Can one assume that if one hears 4 chital alarm calls in 5 minutes there are more chital present than if one hears only 2? No! A lion who has long held a territory against few competitors may roar infrequently. A lion who has recently won a territory and has many competitors may roar much more often. Moonlight, females in oestrus, state of hunger etc. may all affect roaring.

If one starts with the premise that a call does indicate animal presence, then the recording of calls from several separate sites in a short time interval can be used to give a minimum estimate of the number of individuals in an area. Variations of this technique have often been used with birds.

Bird Calls:

The males of many bird species use calls to indicate territory ownership or to advertise for a mate. Species vary from tiny song-sparrows to large bustards, cranes and ground hornbills. Production of calls varies seasonally, being most frequent at the start of the breeding season, and varies diurnally, being most common at dawn, and sometimes at dusk as well. Weather changes may affect vocalisation. The first prerequisite of a census based on calls is to choose the appropriate season and appropriate time of day.

In some cases it may be possible to stimulate a bird to call by playing calls from a tape-recorder. This technique is often used with pheasants, who view the call as an intruder in their territory and will call back to the intruder.

Note that these methods do not directly count females or immatures, or possibly even non-territorial males - only adult calling males will be counted. This in itself may be of sufficient value, in that different areas, different years and different management activities can be compared.

Census Operations:

1) In hilly terrain, such as in most pheasant areas, it is possible to find vantage points on ridges or hill tops, from where calls from several areas can be heard. (Pay attention to wind direction when planning listening sites, wind greatly affects your ability to hear calls). A complete hill-valley system could be covered in such a way by a series of observers. Double counting can be eliminated by recording the time of each call, its direction (use a compass), and approximate distance away. By comparing adjacent observers' notes and using a good map, double calls will be prevented.

Such vantage points can be used to play back bird calls, but again remember that down-wind response will be much greater than up-wind.

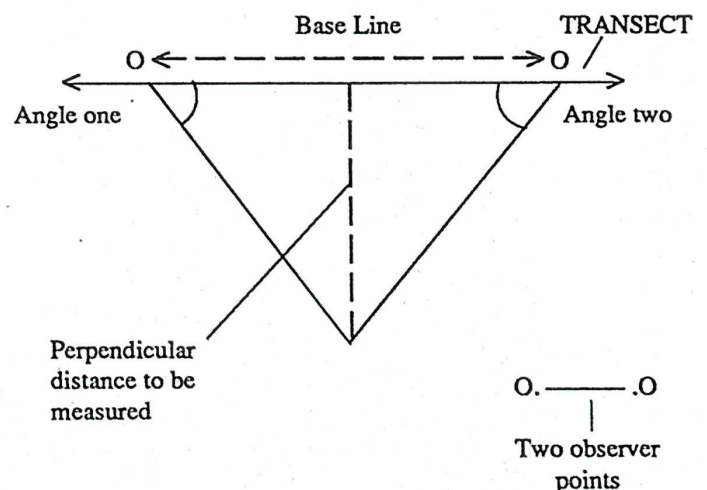
Data on number of calls can be used directly as indices of population abundance; or, by knowing the area which has been censused, (how far can you hear a bird calling?) an estimate of density can be made. Hill systems allow such area measurement, as ridges will be prominent on maps and when locating calls.

2) In flat terrain, such as sal forest in the terai, it is possible to census jungle fowl by recording calls heard whilst walking along transects.

There are many variants of this method. The observer should walk slowly and silently along pre-planned transect lines at the optimum time of day and year. I prefer to stop every hundred metres and listen for a full minute, turning to face all directions. When a call is heard the location should be noted including your position along the transect (e.g. between 450 and 500 metres, bearing 060 degree and approximately 40 metres distance).

In this case you are getting information on the number of birds heard calling along a sample transect. It will be necessary to run several transects to get adequate data on a particular area. Data can be used as an index of abundance. In this case the average number of calls per kilometre of transect will be the value to use to compare habitats, years etc.

Estimates of the density of calling birds can be obtained by knowing the width along the transect in which you can hear calling birds. The perpendicular distance to a calling bird from the transect line can be estimated by guess work, or calculated as follows. On hearing a call a compass bearing is taken, a short distance is moved along the transect, counting metres walked, and another bearing taken on what is assumed to be the same bird still calling. The two angles and base line distance are drawn on paper (graph paper is best) using protractor and the perpendicular distance is measured, e.g.



The conversion of a number of calling distances to an estimate of how wide a transect is covered is problematical. One solution is to take the maximum distance and use this as the estimate of strip width.

Strip width and transect length give you the area necessary to calculate the density of birds calling:

$$\text{e.g. Density} = \frac{n}{L \times 2W}$$

Where n is total number of birds heard calling summed over all transects.

L is total transect length

W is strip width, the figure 2 is to cover both sides of the transect.

The density value can be calculated once for all transects combined or, in order to get confidence limits around the estimate density, it can be done separately for each transect. In this case transects should be long enough to ensure a few birds are heard on most occasions. Strip width however is best calculated from the overall data set and the same value used for each transect. (See section 2.3.3 for more details of this formula).

Each separate density estimate for each transect can then be used to give an estimated mean density with a measure of variation. Transects of different lengths may need to be weighted; equal length transects are easier to deal with. Norton-Griffiths' book "Counting Animals" gives formulae to use for unequal length transect lines (see reference list).

Extrapolating to total populations:

So far we have considered male calling birds. If extra field work allows the observation of natural groups of the birds, then male: female ratios and male: immature ratios can be recorded. If the data set is good enough it can be used to determine total population density, knowing the density of males:

e.g.

Male density 3.5 per sq km

Observations 24 groups.

Male : Female = 1 : 2.4

Male : Immature = 1 : 0.8

Total population density

= Males (3.5) + Females (3.5 x 2.4) + Immature (3.5 x 0.8)

= 3.5 + 8.4 + 2.8

= 14.7 per sq km.

2.1.6 Fixed Visibility Transects For Monitoring Population Trends

Introduction:

Some protected areas in India have developed a series of permanent transects for monitoring population abundance. The most widely known of these is the Palamau Track Census Technique, developed in Palamau Tiger Reserve, Bihar, and used there for over 15 years (See Bibliography, Section 4). The method assumes a constant fixed width visibility either side of the transect or track, and it was suggested by them that even if the width is wrong, the results still give a useful index to population change. This, however, may not always be true, as we discuss below.

Permanent Transects:

In Palamau, some 60% of the whole reserve has been crossed by a network of permanently marked straight line transects (using paint marks on trees). Transects are at fixed intervals of 400 m and are parallel in each block in a direction chosen to facilitate walking from one access road to another. The transects vary from 1 to 5 km long.

In the early days, just the numbers of animals seen were used as the index of population abundance, e.g.

	1970	1971	1972	1973	
Chital	597	625	541	623	(Note: These data are for 249 sq km only)
Sambar	139	148	125	160	

No assumptions were made about all animals being seen or not, the results were purely an index, and as such, the results from 1970-73 would indicate a population which is stationary.

Fixed Width Concepts:

In later years the Palamau authorities chose an estimate of 50 m as their measure of lateral visibility either side of the transects. This gives a 100 m wide strip every 400 m, and hence results are multiplied by 4 to extrapolate to a total count for the whole area.

The following data set has been obtained in such a way in recent years:

	1982	1983	1984	1985	
Chital	23,071	17,476	18,399	15,657	(Note: These data are for 900 sq km)
Sambar	4,049	4,097	5,307	3,850	
Boar	13,509	14,322	11,498	8,576	

This data has been taken to indicate a decline in species numbers, but is this necessarily true?

Discussion

For any index to work, conditions have to be uniform throughout the duration of the census period, the only parameter that may vary is the number of animals. If, for, example only half the people were used in one year, a fall in numbers could be expected.

In Palamau, the authorities have assumed visibility has remained constant over the years, and that results indicate a real change in numbers. However, at the same time they acknowledge that forest protection has caused an increase in shrub density, grass height and forest regeneration - all parameters which could be expected to cause a decrease in visibility. Their initial estimate of 50 m must have changed.

We suggest therefore, that no conclusion can be drawn from these data, as there is great uncertainty about a key parameter - visibility. The method is no longer suitable as an index.

How can the method be improved?

Staff and trainees of the Wildlife Institute of India undertook a combination of census methods in 1986 and 1987. Our small sample of visibility estimates in December 1986, showed a mean of 40 metres, varying from 22.5 m for langur to over 100 m for elephant; chital mean sight distance was 35 m. Palamau authorities will have to measure visibility each year, either from a proportion of animal sighting distances, or from a number of fixed posts specifically set up to estimate visibility. Our King census foot transect operation gave consistent results from 1986 to 1987.

2.2 USE OF INDIRECT EVIDENCE FOR ACTUAL POPULATION ESTIMATION

To convert quantitative data on indirect evidences (e.g. dung pellets per ha, tracks seen per km walked, calls heard per hour etc.) into estimates of actual population size (e.g. 16 tigers in this range, or 12.9 chital per sq km) is difficult.

Such conversions depend on knowing accurately the rate of production of the evidence, and for how long that evidence remains visible. How many times does a chital defaecate in 24 hrs, and for how long are faecal pellets distinguishable?, are pertinent questions. But they are difficult to answer, as will be explained below. Even apparently simple parameters, such as the frequency with which an animal takes water, are complex to determine, as they depend on so many variables, and they can only be very coarse estimates at best. A recent study on elephant dung density, rate of defaecation and rate of decay of dung heaps discusses the possibility of this technique in South India (Sale, Johnsingh, Dawson, 1990 IUCN/

SSC Asian Elephant Specialist Group). The conclusions are that the method does have great promise, and needs further refinement.

Another possible method to convert indices to actual estimates of abundance is to use a different and direct method so as to calibrate data from indirect counts. For example if in a small restricted area there are only 35 chital, and there are 180 pellet groups per hectare per week, then knowledge of the proportion of dung per chital could be used to estimate population sizes elsewhere.

Finally, evidences may be related to individual animals, such as identifying large carnivores by their pug marks, and searching an area until all individuals are so identified. This technique, the basis of carnivore population estimation in India, is described below in considerable detail.

2.2.1 Pugmark Counting for Large Carnivores

Introduction

The technique of censusing tigers was first developed by Chaudhary and applied for counting tigers in the state of Orissa in 1969. Later the first all India census was carried out in 1972 which employed the technique by then called the 'Cooperation' census since it involved a large number of professionals and local people. The census methodology is described below, considering contributions made by authors before and after Chaudhary. Reference are given in Section 4.

The Tiger Pugmark

The census is based on recording several distinguishable morphological features of tiger's footprints or the pugmarks because studies have shown that each tiger in a defined area has a "unique" pugmark signature which makes it possible to distinguish individual tigers in the forest. The overall shape of the pugmark helps in determining the sex. Fig. 1 depicts a typical print of the rear left foot of a tiger. The terms used in distinguishing the key identity features in the process of pugmark analysis are indicated. The process is discussed separately.

Where to Look for Pugmarks?

The smallest unit of survey and census is the forest beat, also called the counting unit which bears a permanent serial number. The person in charge of the beat survey is called the participant. Tigers mostly walk along a well defined network of forest roads, paths, wildlife trails, stream banks. They choose well beaten paths and frequent water points like all other wild animals. A census participant therefore must have thorough knowledge of such features within his area i.e. counting unit. If a tiger is present, survey along such favoured areas especially in summer, must yield pugmarks.

Preparing Tiger Pugmark Tracings

a) Equipment: The principal requirement of the census is the detection and record of tiger pugmarks. The equipment necessary is a tiger tracer, sketch pen, tracing paper, field note book and ball pen, prescribed census format, topographic counting unit/beat map, a large scale range map showing counting units, a 2 metre tape, plastic mug, plaster of paris and a water bottle. It would be ideal to provide a field compass to each participant.

b) Pugmark Selection and Tracing: Great care is required to select a 'representative' pugmark. The method is based on the assumption that a trained observer can accurately draw the key features of an individual pugmark. Best prints are obtained on hard and even open surface overlaid by a film of dry or moist fine soil about 5 mm thick, or a compact fine sandy surface. Prints obtained on large grained dry sand, stony soil, muddy surfaces, deep fine soil are usually distorted and not representative. Examine the trail and select a print of the left hind pugmark on the best possible substrate. Make sure that all edges of the foot print are registered and are as sharp as possible. Place the tiger tracer on top of the print so as to get the print in the central position of the glass. The gap between the print and the glass must be uniform and as narrow as possible to avoid parallax when the print is viewed from the top. The glass should not however touch the upper edges of the print. Angled lighting shows the print features to best effect. Morning and late afternoon hours are ideal. Position yourself on the ground, on knees to bring your eyes vertically above the print and close enough to see all print features clearly. Study the print carefully and satisfy yourself about the clarity of the edges of toes and pad, then using the sketch pen, trace the sharpest outer edges of all toes and pad and any recognisable lines within the toes or pad composition smoothly. Check and correct lines if necessary. Some participants prefer using a series of dots along the edges and then join these by drawing a line. During the process of tracing, maintain the position of your eyes vertically over the print segment being traced. If you change the position or angle, distortion will result due to parallax.

When the trace is complete, mark the direction of walk vertically on the tracing partially cutting the leading edge of pad and the second toe. Draw a tangent at 9'O clock to the marked direction of walk at the upper most point of the leading pad edge (Fig.2). This grid helps in ascertaining differences in lead pad edge inclination while comparing traces. Remove tiger tracer, place a piece of tracing paper the size of tiger tracer glass, hold it firmly over the glass by clips or rubber bands. Hold the tracer against light so that the tracing on the glass is clearly visible through the paper. Trace this on the paper carefully without errors. Write with ball pen your name and counting unit number in top left corner of the trace, location of the trail of pugmarks by a landmark in the right upper corner with date and time. In the lower right corner of trace describe substrate, the normal walk, foot fall sequence, stride/step, sex, age class of the animal, print age

(A, B or C) and the direction of walk (see details below). Preserve the pugmark traced on the ground by surrounding with small stones and placing a flat stone across and resting on the ring for verification by a supervisor.

Right rear pugmarks can also be selected but if different enumerators in nearby counting units select left and right by their individual choosing, subsequent comparisons in overlap zone may become difficult. Hence for uniformity the left rear pugmark has been prescribed for preparing traces.

c) Determination of Normal Walk: Footfall Sequence: Follow the trail of pugmarks over as great a length as possible, ideally over 500 m at least and observe carefully the footfall sequence. There are six basic patterns (i) hind foot completely registering over the print of the front foot hence only the prints of hind feet are obtained (ii) hind foot print completely over shooting the front foot print (between distance important) (iii) hind foot print under shooting the front foot print (rare) (iv) hind foot print partially over cutting front foot print (v) hind foot print partially under cutting the front foot print (vi) lateral and partial superimposition of hind foot print over front foot print. It is possible that within a single trail two or more patterns may be seen due to gait variation but the commonest sequence should be taken as the normal walk for the specific animal. Census procedures for a given state must ascribe a code notation for each pattern. The appropriate code should be recorded on the trace as the case may be. This is corroborative information (CI) for resolving close identities based on morphology of the print alone.

d) Record of Stride/Step: A stride is the distance measured in centimetres between two successive prints of either the left hind or the right hind foot as a result of a single complete movement of the particular leg. A step is the distance measured in cms between the successive left and right hind foot prints measured vertically between parallel tangents drawn at 90 degrees to the direction of walk consistently either through the highest point among toes or through the lowest point on the heel. The step measure half as much as the stride. Chaudhary measured 'step' distance and called it a stride. So long as a term is defined and uniformly applied it does not make a difference. Record at least 5 to 10 measurements at random along the trail of the same animal on approximately plain section. Avoid slopes. Work out the average stride/step.

e) Identification of Sex: Draw a four sided right angled polygon around the tracing of the print, touching the outermost point of the print on the respective sides (Fig.3). If the polygon is nearest to a square the tiger is probably a male. If it is a clear rectangle the animal is probably a female. Observe the over-all shape of toes. Males tend to have toes nearer to a circle. Female toes tend to be near to an oval. The front foot prints of a male and female (when obtained) do not make such distinctions, hence the hind feet prints are important as determinants of sex. If there is confusion about the sex of the animal, record it as sex unknown.

f) Determination of Print Age: This can be achieved very crudely. It is highly subjective but is better than not having such a judgement at all. The information is noted at 3 levels — A, B and C. A indicates very fresh pugmarks, clean and sharp edges, no fall-in of soil. B indicates relatively recent pugmarks, well defined features but some obliteration of edges due to wind. C category indicates older pugmarks with diffused and obliterated edges: age class indeterminant. Such estimates help a little in sorting pugmarks otherwise close in appearance from separate sites. Date and time of record and estimated pugmark age provide a clue.

g) Use of Plaster of Paris: An often used alternative to pugmark tracings is making plaster casts of prints by using plaster of paris. By mixing water in plaster of paris powder a viscous mass is prepared which can run when poured but is not watery. It is evenly and quickly poured over the selected print. Sticks are used to make a temporary square frame which is put around the print. This holds the volume of wet plaster and prevents it from spreading out. Good plaster should set quickly and dry. When dry it is carefully prised out and the lower surface is carefully cleaned. A true replica, “a negative” is obtained. Information is inscribed on the reverse surface by a nail. In spite of the obvious advantage there are problems with casts. They are inconvenient to handle. Large space is required for studying 200-300 casts. It is very difficult to sort them. Casts often break when plaster is of poor quality. Casts are three dimensional, made under varied soil depth situations, they are that much more difficult to use for precise comparison and analysis.

h) Substrate Problems: Certain forest situations pose serious problems relating to substrate quality as a result pugmarks are rarely seen e.g. terai and evergreen forest habitats. Only wet patches may yield pugmarks. Wildlife trails and earth roads over dry surfaces are generally hard packed and unsuitable for pugmarks. When such a situation arises employ the use of a systematically laid network of Impression Pads (IP). On earth roads and wildlife trails the IPs are located at approximate intervals of some every 500 meters. Across the road or trail an area covering the width of the road or at least 4 meters wide, whichever is more and equal in length, is evened out. Gravelly or stony material lying loose on the surface is swept off and a uniform thin layer of fine soil or sand is spread over the surface. This IP is ready to register footprints of animals walking on it. All well beaten paths should thus have IPs on which tigers must walk at one time or the other. Similarly IPs can be provided near water-holes with unsuitable substrate surrounds the approaches and margins. IPs are numbered, mapped and regularly monitored for pugmarks. Such preparation if considered necessary must be ready well before the census is scheduled to begin.

i) Typical Pugmark Related Questions:

I) Difference Between the Front and the Hind Foot Print: Footfall sequence permitting, all the four feet of the

tiger may register prints. Census focuses on the prints of left hind foot. The hind feet prints can easily be distinguished from those of the front feet prints if the observer knows what to look for. The front feet prints are appreciably larger than the hind feet prints and less distinct on the same substrate. The hind pugmark shows the three heel lobes almost of equal size and a tangent drawn will touch the outer points of all the three lobes. The front pugmark has the two lateral lobes prominently displayed. The central lobe is appreciably smaller and not in line with the other two i.e. a tangent drawn to touch the outermost points of all lobes will touch the lateral two lobes only leaving a gap against the central lobe. (Fig.4)

II) Distinction Between Pugmarks of an Adult Leopard and a Tiger Cub: A tiger cub with pugmarks the size of an adult leopard would be between 3 to 4 month old. At this stage it is too young to move on its own and always is accompanied by its mother. If such small prints are seen accompanied by prints of a tigress, usually the smaller prints belong to a tiger cub. However an observer is quite likely to encounter a situation wherein a path is used by a tigress and an adult leopard separated in time. Record the prints and observe. Adult leopard pugmark is compact, the toe spread and toe advance is distinctly narrower than that found with a tiger cub pugmark (acceptable substrate only). Another important thumb rule is that the ratio-fraction between toe-size and pad-size is smaller in case of a leopard as compared to that in case of a tiger i.e. for the same size of pad the toes of leopard will be distinctly smaller than those of a tiger. You need to have a reference. All census areas must have such an example on record to enable observers to appreciate the difference.

III) Distinction Between the Left and the Right Pugmarks: Inexperienced observers often ask such a question. Whichever the foot, the outermost point of the second toe leads all the tips of other toes. This actually is the third toe. The first or the dew claw being situated higher up on the leg does not register. If the longest toe as we may call it is second right it is a right foot print and if second left it is the left foot print. In deep mud, deep fine soil the dew claw may register by the side of the first toe. On slippery muddy banks large claw marks may register in front of each toe. This is exceptional and need not cause confusion.

IV) Determination of the Age Class of the Tiger: There is no known technique by which the age of the tiger can be estimated by pugmark features and size. The census format has three categories adult, sub-adult and cubs. Cubs are taken in the sense of very young animals, say up to 6-8 months old. The census does not define this. As per convention a young tiger not yet fully separated from its mother, between 15-20 months age is still referred to as a cub, though it may look as large as its mother. In a broad sense pugmarks smaller than an established average adult male or female pugmark size but not to be confused with a pugmark identified with a ‘cub’ size animal as above is recorded against the sub-adult animal category. Admittedly this is a bit crude. The following criteria be used to classify tiger pugmark by size (length) on

comparable substrates in the three age class categories (a) length > 12.5 cm: adult male, > 11.5 cm: adult female (b) length < 9 cm: cub (c) all intermediate measurements: sub-adult animals. Pugmark length is measured vertically between parallel tangents drawn to touch the tip of longest toe and the outermost point of the lowest heel lobe. (Fig.3)

Other Tiger Signs

No tiger signs except pugmarks can be used to identify individual tigers or to estimate their number. It is of course possible to make use of tiger signs to derive indices of relative abundance, (more about this later). In addition to pugmarks which are the most conspicuous evidence of tiger presence, signs such as scats and scrapes, claw marks on tree boles are useful indicators of tiger presence and could be recorded in terms of number per km length surveyed. These are not as frequent and as easily detected as the pugmarks. Look for scats along the middle and sides of road/path. Scrapes are often associated with urination and scats. Fresh scats which smell 'high' can be detected when observer is downwind. The smell is often mistaken for a rotting carcass or nearby presence of a tiger. Old scats are often only aggregates of bleached hair remains not easily detected unless the participant is actively looking for it. Scats are more difficult to encounter in rains and early winter when dung rolling beetles are active and quickly remove all material except hair remains. Claw marks made by tiger are usually found on tree boles with soft bark e.g. *Bombax ceiba*, *Madhuca latifolia*. Claw marks are deep with sharp edges, placed vertical or at an angle and may reach up to 2 m height above ground or more. Look for hair sticking along marks on the bole of the tree and loose pieces of nails. If the participant has a good nose, fresh tiger marking can be detected as a strong cooking rice aroma. It also suggests that a tiger is likely to be nearby. Tiger presence can be detected also by calls which are quite distinct. This however is by no means a common place event since tigers as a rule are not as vocal as lions. All evidences should be tied to locality and recorded.

Tiger Sighting

Sightings should be recorded separately with mention of date, time, locality, distance at which observed, adult or otherwise, sex if identifiable and activity details. When the tiger moves away, the pugmarks must be verified and recorded. Sighting does not confirm identity, and cannot be added to the tally.

Census Format or Counting Sheet

The format prescribed is in the form of a single sheet (Fig.5). The information is straight-forward. Participant should keep the daily observation record in the field notebook and then enter the details in the log book provided in the format. Additional information should be written on plain paper and attached with all traces.

Census Planning and Organisation

The notice regarding census dates and period is issued by the state Chief Wildlife Warden. It applies to all possible tiger habitats and to the concerned management agencies such as territorial divisions, forest corporation areas, PAs etc. Census is carried over a period of one week. In the north-east it is held in February, in the rest of India in April or May. All India census is carried out at an interval of 5 years. The tiger reserves and the better supported PAs make annual estimation. Infact the population should be monitored by information gathered continuously the year round.

The census is conducted over 4 distinct phases within each forest or corporation division or a PA i.e. a division level management unit. The phases are (i) organisation, (ii) pre-census training, (iii) census operation spread over 7 days in two regimes: regime I - first 5 days; regime II - last 2 days, (iv) data collection, analysis and finalisation of tiger tally. The features are as under:

i) Organisation: The personnel hierarchy for the pur-

Sl. No.	Designation	Jurisdiction	Function
1	Participant: Forest Guard WL Guard.	Forest beat/counting unit.	Survey and data collection as prescribed.
2	Coordinator, Section Forester.	Forest section. Includes several beats/counting units. Ideally not more than five.	Coordinate and supervise work of participants concerned. Also gather data.
3	Organiser: Range Forest Officer.	A Range. Includes all sections in the range.	Overall control and supervision of census in the range. Gathering of tiger evidence whenever encountered.
4	Chief Organiser, Deputy Conservator of Forests/Wildlife Warden, PA Director or Supdt.	A Division; or P.A.	All ranges within jurisdiction. Complete control and supervision. To be assisted by Asst. Conservator of Forests. Data collection, analysis and preparation of final tally for the jurisdiction.
5	Chief Coordinator: Officer selected by a State.	A State.	Full charge of census operation in the State. Collection of state data, analysis and finalisation of census data for State.
6	Zonal Coordinator.	States as grouped under Zones: North, East, Central, West and South.	Within and interzone coordination. Data analysis — between state and zone data leading to the all India figure.

pose of the census and their duties are as given in previous page (see table).

For planning and organisation purposes a division level operation is considered. The chief coordinator arranges training of chief organisers as the first step. Chief organisers need to be experienced persons. The State Wildlife Wing takes an active part in all aspects of the census. Regional wildlife wardens within the state must lend their expertise and extend supervision in non PAs.

At least a week before the pre-census training for participants is scheduled to begin, the chief organiser must ensure that all equipment is ready and logistics are planned as shown below:

- i) Division level large scale maps of previous census operation with identified tiger locality and individuals mapped.
- ii) Forms and tracings of previous census and analysis.
- iii) Range level, section level maps in sufficient number for the use of organisers and coordinators.
- iv) Counting unit maps for participants.
- v) Topo-sheet sets at range level for reference.
- vi) Cut pieces of tracing paper in sufficient quantities, sketch and ball pens, field notebooks, census formats, tiger tracers, 2 metre tapes, hand compasses to meet the requirement of all participants.
- vii) Communication and supervision schedules, wireless operation, vehicle assignments, format collection, verification, submission, data analysis and result schedules.

All equipment from range level downwards must be distributed and should reach individuals concerned. All planning and operational details at appropriate levels must be communicated.

ii) Pre-census Training: Ideally 7 working days should be devoted. Training is imparted and coordinated by experienced officers. All men to be engaged are addressed about the methodology, individual responsibilities, supervision, verification schedules. Participants and all observers are put through the complete drill of census procedure and assessed for competence. This is practical work. Lots of details must go into this. Familiarisation with terrain, map reading, habitat description, calibration of substrate conditions, study of wildlife signs with emphasis on tiger signs, survey and record preparation. Continuous practice at pugmark selection, study of morphology, foot-fall sequences and tracing is critical. Only practice can iron out the variations between individuals. The importance is often not understood. Census supervisors must satisfy themselves of the standard and level of participant preparation. Supervisors must lead the participants in census training.

iii) Census Operation:

Regime I (First five days): Each participant works for at least half a day. This condition is for non-PAs with consideration to peak forestry activities which would preclude taking away men from their tasks for seven full days at a stretch. Over the five day period participants must try to cover as much of the counting units within the potential tiger areas as possible, and gather evidence. Supervisors must verify pugmark tracing on sites in the field through a predetermined communication schedule. It is possible for a senior supervisor to cover 500 sq km in one week and verify all traces over the entire seven day period.

Regime II (Last two days): Intensive repeat of survey. Visit areas not covered earlier, check for new evidences and record. Obvious multiple evidence for the same animal must be identified and noted in the counting unit summary. Organisers, coordinators and the chief organiser must play a key role. Objective is to analyse the data progressively in the field itself.

iv) Data Collection, Analysis and Result:

Participants	: Handover completed record to the concerned coordinator who collects it for the section.
Coordinator	: Submits collated data for section, complete with verification to the organiser.
Organiser	: Collects data for the range. Verifies it; the officers assisting the chief coordinator take active part in this.
Chief Coordinator	: Receives data from all organisers, analyses the data and finalises the tally.

The analysis of information or the process of establishing tiger identities must be carried out by an experienced person who is familiar with the total area concerned. It is not just a mechanical process but needs experience and judgement. It essentially involves comparing pugmarks/traces i.e. the form and related information from adjoining units and elimination of duplication. It should begin with one section and then the analysis is extended to include larger and larger areas by adding further sections. It is to be remembered that the process cannot be complete and correct unless the traces being sorted out as separate individuals are repeatedly used in comparisons as more and more sections are taken up for analysis. Knowledge of tiger sociology and land tenure systems is critical. It is convenient to use pugmark 'form' categories to sort out pugmarks initially. ('Forms' as described by Jayarajan 1983). While comparing traces it must be ensured that the substrate in context are similar. Analysis of previous census with maps must be used. The final identities should be put on the division scale map in the units concerned. Corre-

sponding traces must be superscribed to that effect. Compare with previous census information and assess dispersal of the then sub-adults, the fate of adults, new additions, shifts in locations. Comment on problem encountered and gaps in information.

Discussion on Pugmark Methods

1. Whilst pugmark census has been widely accepted in India and is in widespread use - it does not follow that the method is simple to use. Panwar in his paper says 'painstaking care is necessary at every stage'. Karanth (1988) is even more sceptical about abilities of disinterested field staff to use the method. Like all other field techniques, its optimum use depends upon experience. It is probable that experienced and interested persons can distinguish a large number of individual animals from a set of collected pugmarks. But it is equally probable that the inexperienced or disinterested managers will make many mistakes in individual recognition. Practice makes perfect and managers should not view pugmark examination as an exercise to undertake only once every one or two or even four years. Pugmarks should be examined whenever the opportunity arises. Junior staff cadres likewise should be encouraged to collect data at intervals throughout the year. Managers must train, encourage, stimulate and supervise use of this technique.

2. Pugmarks are a means to identifying real live animals, they are not an end in themselves, instead they should lead to the recognition of real animals. Whenever a carnivore is seen in the field, its pugmarks should be described and the animal characteristics noted - sex, age, size and distinguishable features. Done over a period of months this practice can result in the ability to recognise individual animals from their pugmarks; and will make the observer a better judge of pugmark characteristics.

3. Giving such identified animals a name can greatly increase your ability to recall individual animal characteristics

and it can also increase the level of knowledge from field staff and mahouts if they too use the same name. It is much easier for example to talk about "Rajah" than it is about "the big male who is often near compartment 4" or even, "the large pugmark with an uneven stride and a small digit on the rear right pug".

4. During census and routine pug collecting operations, great use should be made of maps, the locality of every pugmark collected should be marked on a map. Marks should be annotated to indicate individual animals. Doing this can help draw attention to possible errors e.g. a normally sedentary animal, suddenly being found a long way away, and allow cross checking between identification result from adjacent forest blocks.

Utility of Results

Pugmark data, when well collected and analysed, can yield more information than simply population size alone. The data should also give information on :

- : age composition and adult sex ratio of the population,
- : longevity of individual animals,
- : home range and seasonal changes in home ranges,
- : habitat use patterns, including differences between core and buffer zones etc.

Panwar (1979), using the pugmark tracing method, was not only able to record the growth in tiger population in Kanha National Park between 1972 and 1978 but also to determine changing territorial patterns with growth in population and occupation of new areas, population distribution vis-a-vis habitat suitability and population structure. Thus valuable information on land tenure systems and population dynamics of a typical tiger population was added to the then scarce information on tiger sociology.

Fig. 1. Left hind pug mark of a tiger depicting key morphological features

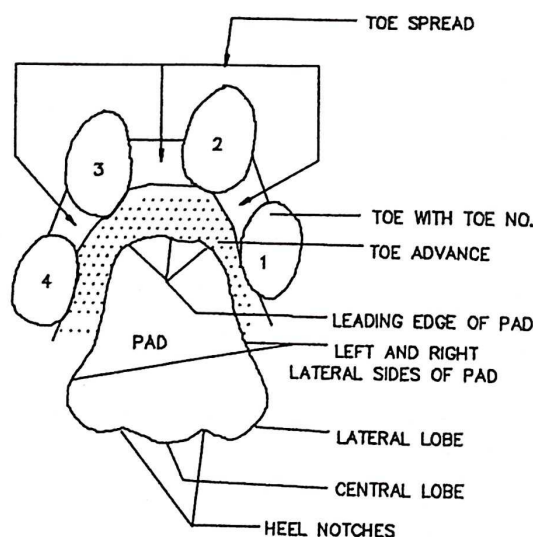
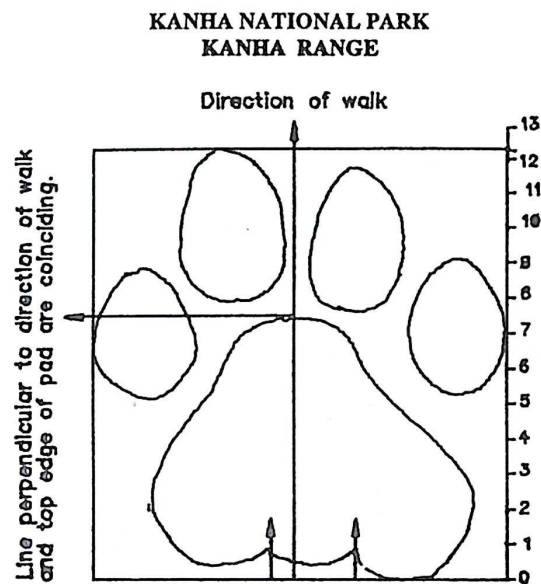
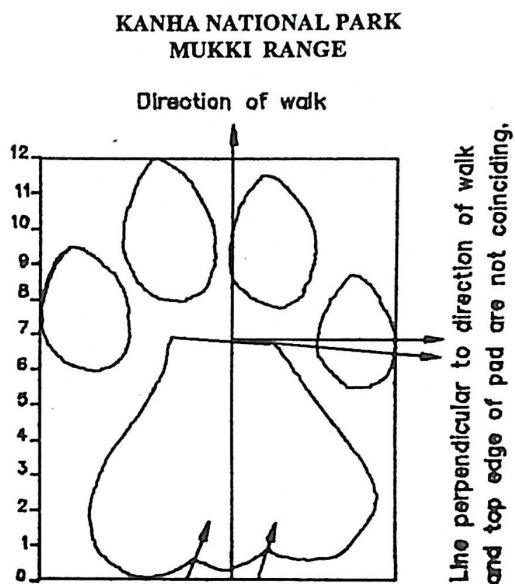


Fig. 2. Use of top edge of pad and heel notches to differentiate between pugmarks of individual tigers (Source: Panwar 1980)



Analytical Notes:

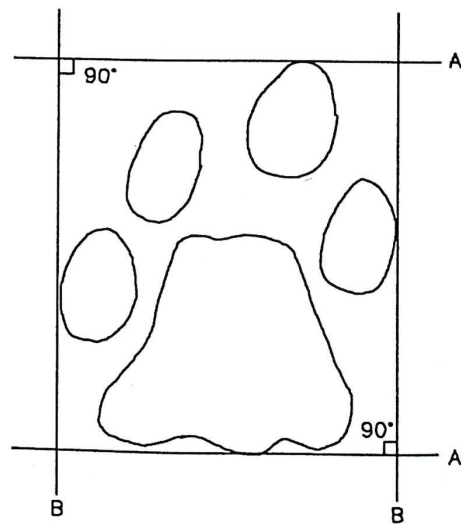
1. Top edge of pad perpendicular to direction of walk.
2. Mark conical tips in bottom edge pointing upwards parallel to the direction of walk.



Analytical Notes:

1. Top edge of pad not perpendicular but inclined at more than 90° to direction of walk.
2. Mark conical tips in bottom edge pointing slightly to the right of the direction of walk.

Fig. 3. Measuring length and width of tiger pugmark



AA - Length BB - Width

Fig. 4. Difference between the front and the hind pugmark of a tiger.

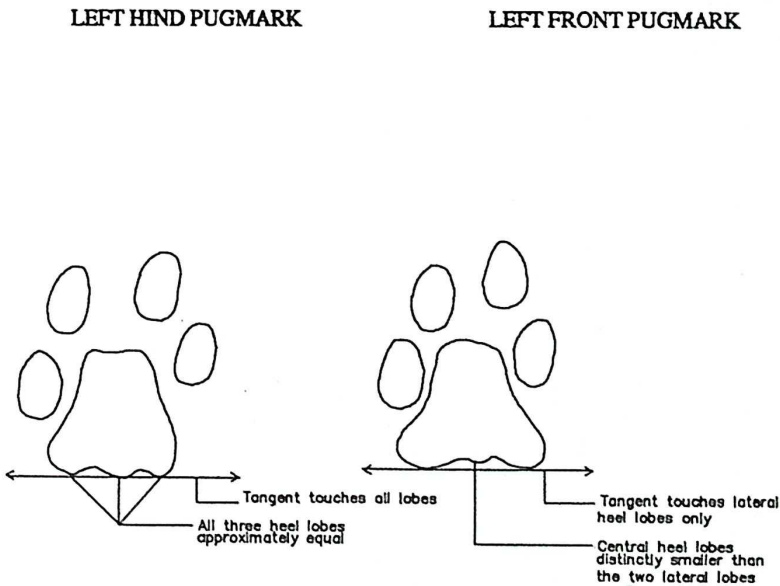


Fig. 5A Cooperation Census Format

COUNTING UNIT NO _____

Species - TIGER (*Panthera tigris*)

Period of Count _____

_____	Division	Name of participant _____
_____	Range	Address _____
_____	Section	_____
_____	Beat/Counting unit	Co-ordinator _____

Overall location of
the area covered
during the week

Terrain : % of — hill ()/hill-plain ()/plain ()

: % of — ravines ()/broken ()/unbroken ()

Cover : a) — Natural preys—abundant/normal/bare subsistence/none left

b) — Human competition—heavy/rational/negligible

c) — Cattle competition—heavy/normal/negligible

d) — Nature of protection—good/fair/bad/worse

e) — Local co-operation—good/fair/nil

Special information from participant

1. If you have not seen a tiger or its pugmark during the week, do you reliably know of any tiger in your area ?

2. Which side was it during counting?

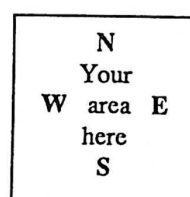
3. When was the last man-eating/cattle lifting ?

4. When was the last tiger seen if none exist now?

5. Remarks of the co-ordinator and other supervising personnel.

Do you reliably know of any tiger in following layout around your counting unit ?

Counting sheet No.?

Counting Sheet
No. ?Counting
sheet No.

Counting sheet No.?

Give details for the above layout as below:

1. How far is the tiger from your area ?
N) E) S) W)
2. What Sex?
N) E) S) W)
3. Has the tiger ever come to your area of count? If so when, and how often?
N) E) S) W)
4. Longest distance covered by you during the week of count, in your area, from the centre.
N) E) S) W)
5. Any other useful information.

Fig. 5B The Week's Log-Book

D a t e	Particular area visited	Time	Tiger seen				Pugmarks seen				Remarks including No. of plaster cast, tracing etc. of pug marks
			M a l e	Fe ma le	C u b	Sex Unkn own	M a l e	Fe ma le	C u b	Sex Unkn own	
1		Morn									
		Aftn									
		Even									
2		Morn									
		Aftn									
		Even									
3		Morn									
		Aftn									
		Even									
4		Morn									
		Aftn									
		Even									
5		Morn									
		Aftn									
		Even									
6		Morn									
		Aftn									
		Even									
7		Morn									
		Aftn									
		Even									

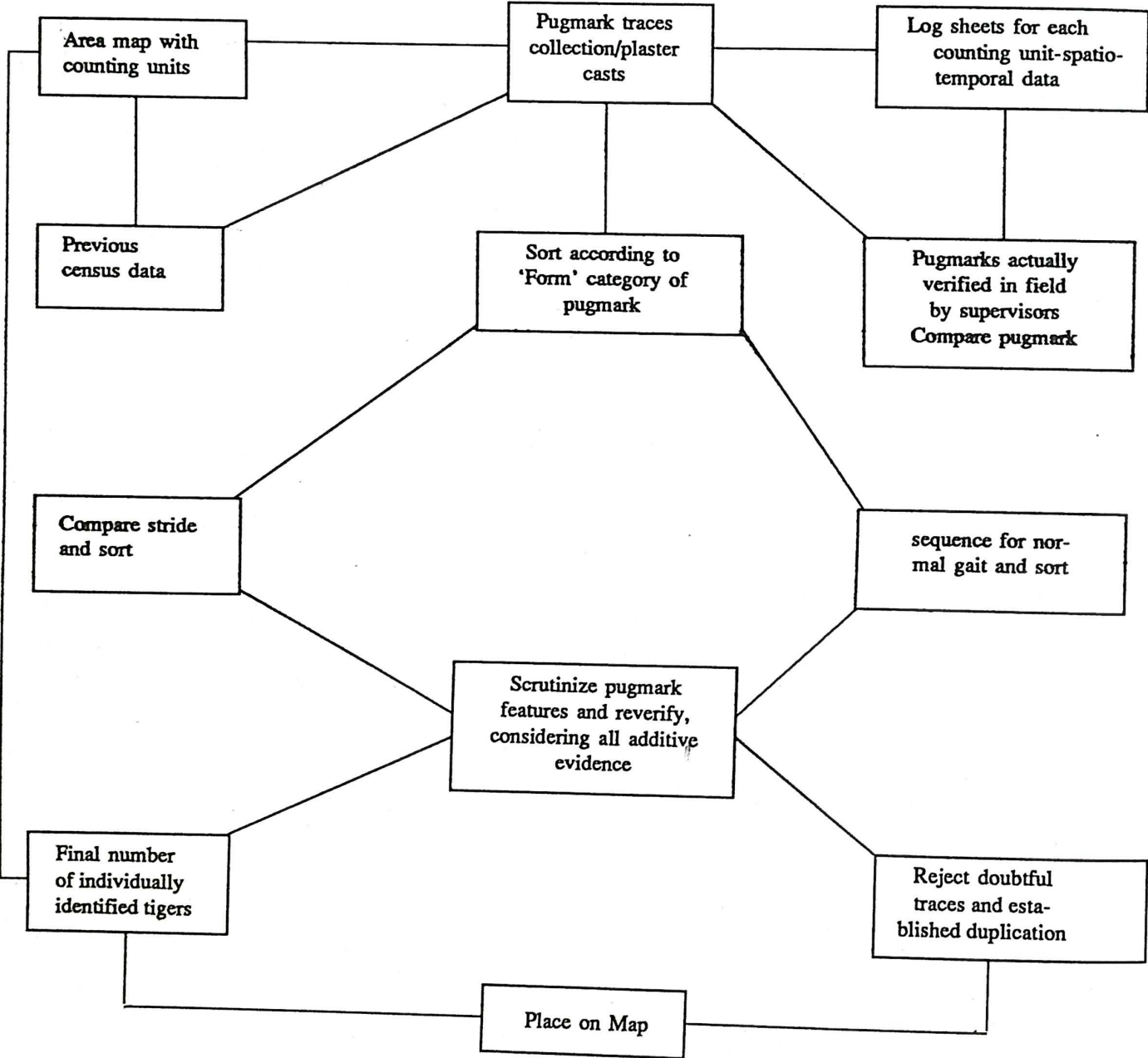
Maps of tiger pugmark location can be examined and gaps with no pugmarks require investigation. Why are there no pugs? Is it inadequate habitat - water, cover, prey? Or it a feature of inadequate searching? If a habitat

feature, then remedial action can follow.

References:

Champion F.W. 1930. Tiger Tracks JBNHS 33(2). 284-287

Fig.6 The Recommended Process for Establishing Tiger Identities
(After - Sawarkar, 1979)



2.2.2 The Use of Dung for Estimating Actual Population Size

A) Using Defaecation Rates.

Introduction:

Section 2.1.3 described methods of collecting data on dung density for use as indices of population abundance. The various assumptions that have to be made were discussed. In many parts of the world, notably North America and North Europe/USSR, the counting of dung is routinely used for estimating actual population size. These techniques have rarely been applied in the tropics. Dung break down and lack of knowledge of defaecation rates are major problems. However, there may be situations where it can profitably be used, so an outline of the method is described here.

The Parameters Required:

The basic information needed is:

- an estimate of dung (faecal pellet group) density per time period,
- information on estimated defaecation rate.

Dung density data are collected as described earlier but the sample sites have to be marked and reassessed after a suitable time interval. Normal practice is for a grid of sample plots to be set up. Each plot is visited, clearly demarcated (but not in a way likely to deter animals from revisiting the site) and all dung meticulously removed (or marked or covered). At a later date the plot is revisited and all dung counted. Plot size and time interval should be such that adequate data is collected with reasonable efficiency. The time period should be such that dung does not disintegrate sufficiently to prevent recognition. The density of the target species and the season of the year will affect sample size.

Let us assume the sample grid is of 100 sites, each of which has a sample area of 20 sq m and that the sample is counted after one month. Assume that in this total area of 2,000 sq m, some 50 dung piles were recorded, giving a density of 1 per 40 sq m or 250 per hectare per month.

Defaecation rate data must come from a separate study. There is much North American data to suggest white tailed deer defaecate some 13 times per 24 hour period, but this figure varies seasonally and with diet type. Other species have different values, and there is sufficient variation between populations of one species to suggest a separate study be done for each area or season.

Many studies are undertaken on captive or tame 'free ranging' animals, and it has been assumed that this replicates conditions in a normal wild population. As there is much social synchrony in defaecation it is probable that captive or solitary tame animals do not exemplify natural conditions very well.

The technique is best described by following a hypothetical example: Let us assume a rate of 15 defaecations by chital per 24 hour time period (a figure which should come from a study for chital in your region, but such information is rarely available).

$$\begin{aligned} \text{Then: Chital Density} &= \frac{\text{Observed dung density in the field for a specific time period}}{\text{Estimated defaecation rate for same time period for a single animal}} \\ &= \frac{250 \text{ groups per ha in a month}}{15 \times 30 \text{ (days in a month)}} \\ &= \frac{250}{450} \\ &= 0.556 \text{ animals per hectare} \\ &= 55.6 \text{ per sq km} \end{aligned}$$

Two sets of figures are necessary therefore. Defaecation rate, and the rate of deposition in the field. This latter statistic is usually obtained by periodic counting of marked plots.

Note: In many studies on North America cervids, a defaecation rate of 13-18 times per day has been determined. One detailed study of chital from Nepal shows a much higher rate of defaecation, of 28 times per day.

Variance and Assumptions:

Remember that estimates of dung density will have a variance, and so will estimates of defaecation rates. The actual confidence limits around an animal density figure will be quite large.

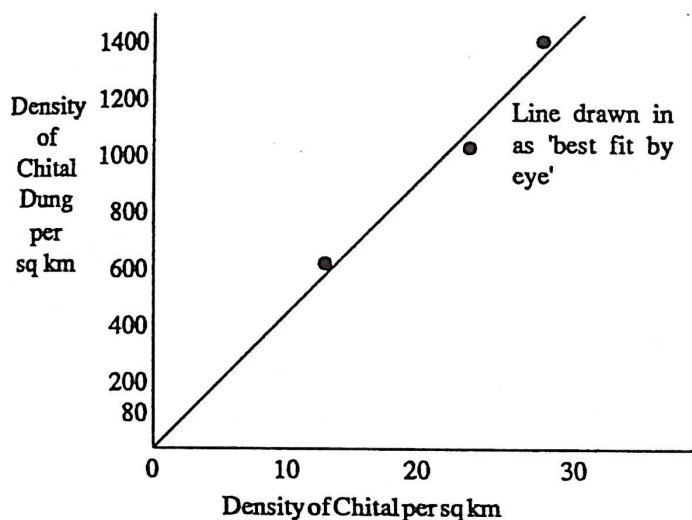
Dung breakdown in the tropics is rapid, due to monsoon rains and dung beetle activity. Winter may thus may be the best season for such census operations. As the defaecation rate figure is used as a constant for a population, data from studies which may be undertaken in the future could be used to correct previous population estimates.

B) Using Proportional Methods.

The counting of low density animal populations is never easy. If you are attempting a census by using actual sightings on sample transects you may have to walk for a long way before recording any observations. If you are comparing compartments and one sample gives 1 sambar and another gives 4 sambar can one really conclude the second has a 4 times greater density? No! Not unless there was a very large sampling effort!

But dung surveys could usefully be employed to estimate animal density, by using proportional values of animal den-

sity and dung density from higher density populations. An example will clarify this: For a high density and medium density chital area we may have figures of 30, 22 and 15 animals per sq km and dung data of 1200/ha, 900/ha and 560/ha. If, in a low density area we find 80 pellet groups per hectare, then an estimate of chital density can be made by proportion. A simple graphical method would be possible remembering zero dung at zero density. A statistician would help construct a regression equation.



Answer is 2.2!

2.3 SAMPLE COUNTS OF ANIMALS USING ACTUAL SIGHTINGS

The counting of animals in a number of small sample units within an overall census area forms the basis for a large number of census techniques, some of which are described here. Theoretically the concept of counting within small sample units is simple. In practice one of the most difficult tasks is to demarcate the actual sample unit and to estimate its size.

Two types of sample unit are considered: counting within blocks, and counting along transect lines. Block counting may either be within a previously known demarcated and measured area, such as a forest compartment; or the block may be described by the start point, end point and lateral positions of a counting team. Transects are merely long thin blocks, which are counted by travelling once along the centre of the transect line, looking outwards to the edges.

Transects may be placed along existing roads or tracks, or placed systematically or randomly within the census zone. Road transects could be covered by foot, cycle or vehicle. Cross country transects usually have to be walked. A technique for vehicle census and one for foot transects are described.

Block counts and transect counts are being used with increasing frequency in wildlife areas in India. These methods are therefore discussed in much greater detail than some other techniques of more limited application.

2.3.1 Block Counts Census I : Planning Considerations

To total count a small area or sample block by one or more people.

These sections discuss methods using direct counting of animals by observers on foot. The methods are suitable for using within steep and rugged terrain as well as in closed forest. Two similar methods are described, one using a large number and one a small number of observers.

Background Information:

a) Total counts become increasingly practical propositions as the area, and so work-load, become smaller. It is perfectly feasible for instance to imagine the successful counting of 10 hectare of forest for chital by one person in one morning. As the area gets larger, or the animal gets smaller or less visible, then the task of counting becomes increasingly difficult. This is not always realised. Many protected area managers in India use some variation of block count in their census operations, but I believe that many of them try to cover too large an area at once, often over 8 sq km, on foot or by elephant.

b) The question of whether one should do a count of selected sample areas and so estimate the overall total from a sample; or attempt to count every animal in every block over the whole area is again relevant. Sample counts have the great advantages of giving estimates of precision as well as being more controllable and causing less disturbance. The block census method lends itself to a sample census design in that a proportion of the total potential number of blocks in the protected area are counted, and a mean density figure, with its variance, is estimated from this proportion. The smaller the block, the more accurately it can be counted; the more blocks that are counted, the greater the sample size, and hence a better estimate of precision can be obtained.

Combining these ideas suggests that the counting of a large number of small blocks within a census zone would be ideal.

Planning a Census Operation:

a) Block counts can be done in two ways, either utilising a single census team, or utilising a larger number of people who systematically cover or beat through an area by walking in an extended line abreast. This is sometimes called a beat or line drive count. Both methods have advantages. The choice of which to use is partly determined by the nature of the terrain, the sample area and the target species.

b) The definition of a sample block is of importance. Sometimes, this can be simple, as when pre-existing compartments are of suitable size (less than 2 sq km) and have well defined boundaries. Otherwise, an area with a high density of streams, tracks and ridges which are clearly defined, both on

the ground and on a 1:50,000 topo-map sheet can allow the drawing of large numbers of potential sample blocks of suitable size on the map. Physical features, such as streams and ridges, as well as roads, fire lines etc., can be used as block boundaries. From the total number of compartments or natural blocks, the required sample can be selected at random (using random numbers, (see appendix) pins on a map or drawing numbers from a hat!). If the compartment or natural feature boundaries cannot be used, then it may be necessary to mark some or all of the boundaries on the ground. This could be done by cutting narrow paths or blazing trees or using markers or even using people as markers.

c) One essential pre-requisite for a line abreast drive count is that there be a clearly defined straight start line along the long axis of the counting block (see Fig.1).

The basic need is for the counters to start together in a line, and proceed forwards together roughly in a line. It does not matter if they reach the finish line at somewhat different distances, e.g. No.1 will finish long before No.7 in the diagram (Fig.1). The finish line should be clearly definable, another track or a large stream are suitable. No more than twenty counting teams (of one or two people) should be used.

The side lines are demarcated by the compass bearings walked by the end counters who only tally animals seen inwards. The area counted can be determined from the map, knowing start and finish lines.

If an adequate start line is not possible, then do not use a line drive. Do not plan a line drive longer than 3 km, as lines start to break up due to slower and faster walking, stops to sight and record animals, and different difficulties of terrain.

d) For block counts, a single census team should cover irregular shaped areas in the most efficient way possible. If a valley-ridge system is to be counted, *then more* effort should be spent in the valley bottoms, which are likely to have more animals in denser cover. Depending on the terrain, the ridges may be walked, looking down into the valley and counting what is seen. Descents into the valley may have to be made to check out denser vegetation etc. If the task seems too big, or if there is worry that some animals may be overlooked, then reduce the size of the area. Divide a compartment using stream beds or tracks, and count each half separately as different blocks *on different days*.

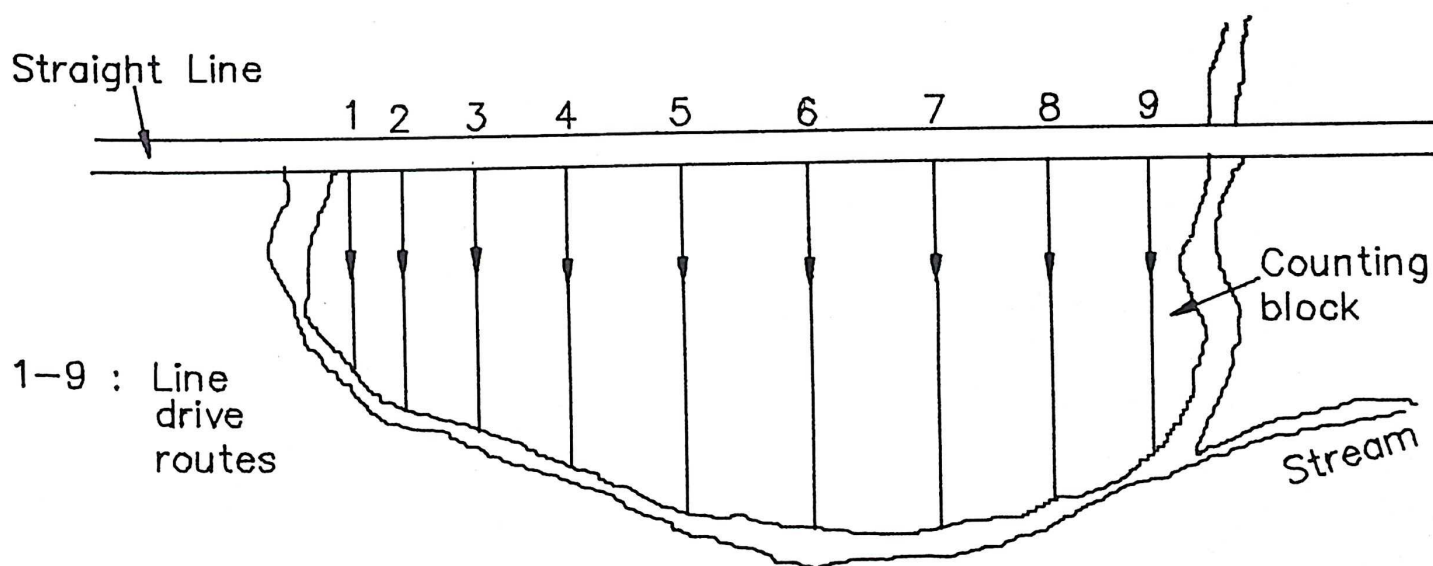
e) Note that an advantage of a sample census is that each sample unit can be counted on a different day, provided the operation is within the same general ecological time unit, e.g. early monsoon or late summer. With three trained counting teams, a total sample of 306 blocks can be finished in ten days.

f) How many samples? (sample size is discussed in the appendix). The answer is how precise do you wish your estimate to be? As a rule of thumb, perhaps 10-20% of the area should be counted. If you have a 300 sq km protected area and you are counting 2 sq km blocks, then 15 sample blocks will give you the 10% cover of 30 sq km.

Like all sampling activities, use prior stratification to increase sample precision. If your protected area has 20% steep hills, 30% grassland and 50% forest then sample each of these strata separately and in proportion to their extent in the area.

Block Count Census II : Field Operations

Diagram showing precensus route planning for a line abreast drive count



Prior Planning:

By the time one is ready for planning the actual field procedures, the sampling design should be complete. A choice of line abreast or single team block counting will have been made. Potential sample blocks will have been drawn and the required sample chosen.

Field Training:

All participating staff should know exactly what to do from prior talks, discussions and sufficient field trials. If necessary make the first day's count a full scale rehearsal and repeat the count later. If one or a few teams are used then it is possible to choose highly motivated experienced people. One of the common problems with most field census operations in India is the use of large numbers of untrained and non-motivated people!

Line Drive Census:

Each person, or a group of two people in difficult country, should be separated from the next group by the largest distance possible without losing sight or sound contact. This may be 20 m in closed forest, 50 m in deciduous forest, and 100 m in open woodland. The method is based on two adjacent observers being able to count all target animals in the space between them. The size and behaviour of the principal target species will also affect the spacing. For example, you could have a wider spacing for chital than for barking deer, which is usually solitary and secretive, and is often flushed from a hiding place at close quarters.

The counting groups are lined up along the start line at predetermined distances apart. Each person or team of two has a simple to use prismatic compass, a sketch map, a counting proforma, a watch, binoculars, a knowledge of the finish line and the identity of personnel to his left and right. This part of the operation, like everything else in census work, should be done quickly and quietly to avoid undue disturbance; preferably details having been covered the night before. See Box 4 How to Walk in the Jungle.

At a prearranged time, the line moves off, walking along a pre-determined and frequently checked bearing; line up a tree or horizon feature ahead and walk towards that. Each group tries to remain equi-distant between its neighbours. It nearly always happens that terrain features move some groups close together. Be aware of this and try and compensate for it by deciding who is off course and moving back onto the correct track.

On sighting an animal or group of animals details are recorded: species, number (composition of group if possible), time of observation and direction from which and to which animals were moving. These last two items are important to avoid double counting, see Box 5 of an actual field example.

Box 4 How to Walk and Observe Animals in the Jungle

Like everything else in wildlife, training is essential. Firstly, observers should move as quietly and unobtrusively as possible; avoiding perfume, after-shave and bright clothing. Stopping and listening every 50 or 100 m is a good idea, essential for primates. Walk slowly and carefully, looking in all directions, including behind. If you think you hear or see something, then stop and look carefully. If necessary kneel and look from closer to ground level. Your eyes should focus on areas close by, 15 m or so, and then move out to 100 m and as far as you can see. Observers should scan patches of shade, under trees, thickets etc. Often only an earflick or tailwhisk attracts the observer to a nearby animal!

New observers should go with experienced people. Good sight images should be formed, what does a chital look like at 50 m in evening light? If one animal is seen, look for others, of the same size, or for young ones, perhaps lying in the grass! A single chital is unusual, there would normally be more.

Be careful! There may be large cats or bears. Avoid walking alone.

Single Team Block Census:

The team should include a person knowledgeable about that particular block (beat officer or watcher). A team of three is ideal. Before the census, the map of the block should be examined and a route marked out, which allows the checking of all areas of the block, paying especial attention to meadows, water holes, stream beds etc. The planned route should be marked on the map, with bearings and with some estimates of timing involved. The planned route should be followed as closely as possible in the field, all major deviations from the route should be marked on the map during the census. A typical route map is shown in Fig. 1a & 1b.

The team needs the prepared map, compass, watch, binoculars and a census proforma. The proforma should state start and finish time. It is a good idea to trace the block map on the rear of the proforma sheet.

On sighting an animal group, the time, species, number and composition of animals are noted, and the sighting position and direction of movement marked on a map.

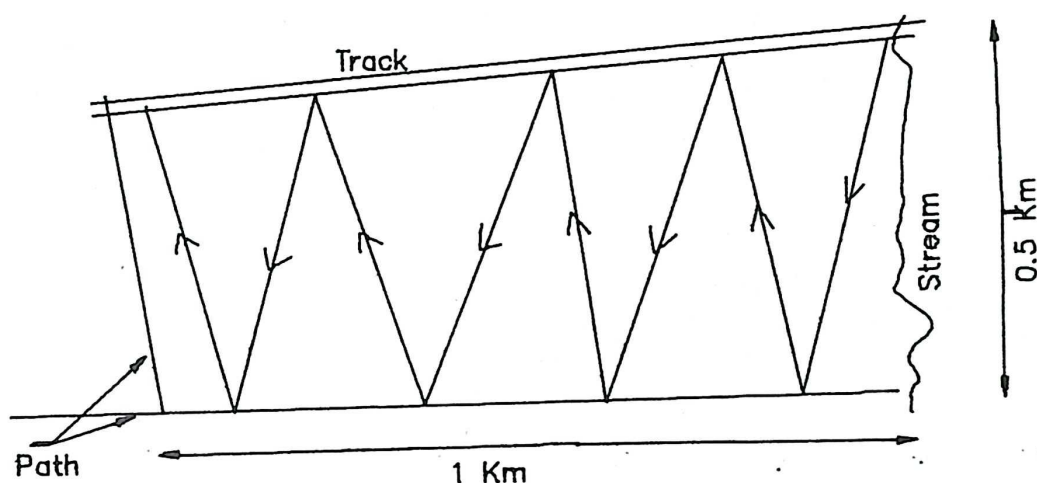
Correction Factors:

It is obvious that large animals are going to be more "easily seen" than smaller animals; and for smaller and secre-

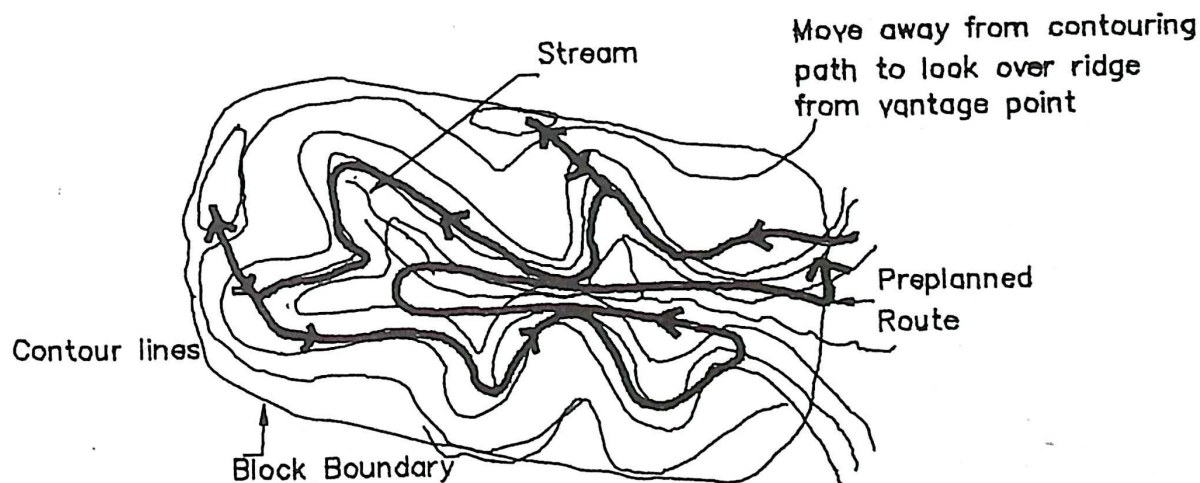
tive animals such as barking deer or boar, counts may be under-estimates. It is not possible to design a single count which is of optimum efficiency for all species. If lines are very close together, so barking deer can be well counted, the time, staff and costs of the whole exercise are increased. The census should be designed for key species, e.g. sambar. This may adversely affect data for barking deer. A correction

factor can be worked out which compensates for this. A few blocks should be recounted at a tighter spacing, i.e. using lines 50 m apart instead of 100 m, or 25 m instead of 50 m for line drive censuses, or the census route should be mapped at closer spacing for single group block census. A small number of blocks should be recounted in this way, say 6 or 7. Details of calculations are given in Section III.

Precensus route planning for a block count in moist deciduous forest



Precensus route planning for a block count in steep terrain



Box 5
Example of the Analysis of a Line Drive Data Set

Sambar : Kalighati area, Sariska National Park, Nov. 1987
(Start 7 a.m. Due West from straight road)

Transect Number	Sambar Seen Per Time Interval					Total	Total Animals Seen	Animals Accepted
	7.00	7.30	8.00	8.30	9.00	9.30		
1.	2f 	1m 2f		1f	3f*		9	6
2.	2f 						2	0
3.	2f		3f				5	3
4.	1m 						1	1
5.	1m				1m		2	1
6.	4f 2y		1m	1f 			8	8
7.	1m			1f			2	1
8.	2f 1y						3	3
9.		1m 3f 2y	3f 1y		1m		1	11
10.	1m 1f						2	2
11.		3f		2f			5	5
	2f 2f					Total	47	41

= animals double counted

* = animals excluded as seen to left on transect, i.e. outside the census area

Census area was 1.8 km², Density is therefore

$$\frac{41}{1.8} = 22.8$$

Block Count Census III : Analysis

Analysis of the Single Block:

a) Line Drive Census:

The census organiser should question each participant as soon as the field exercise is over. Timings and positions should be checked. Someone who completes much before or much after others should be more closely checked. Adjacent counters should then compare counts, starting from the left hand person and moving right. If adjacent teams both have a similar animal sighting at the same time, (i.e. 4 sambar, 1 male 2 females and 1 young, at 07.19 hrs and 07.21 hrs), and movement directions fit, then it can be assumed the same animal(s) have been recorded twice. Only the left hand recorder should keep the sighting, others should delete it. When all sightings have been checked, then a total count can be made. e.g.

Species	Sambar	Chital	etc.
Group 1	6	12	
2	0	4	
3	1	26	
:	:	:	
:	:	:	
Total	27	72	

The actual area of the block should be calculated from the map. Density can be simply calculated from the area e.g. 2.4 sq km, and the number of animals, e.g. 27 sambar, this gives 11.25 per sq km as the density of sambar in that sample block. An example of an actual count is given in Box 5, and a full census in Box 6.

b) Single Team Block Census:

The census organiser should check results with the field team as soon as the field exercise is over. From map locations and animal group details, it may be possible to detect double counting. From actual routes walked it may be possible to detect or see 'gaps' which have not been counted. These can be subtracted from the area of the block (Ideally the field team leader should spot a gap and try to cover it during the actual exercise). Check the mechanics of the operation, add up length of transects walked, and the time taken. I had an instance of one team which reportedly walked 17 km in thick sal forest in two and a quarter hours. Something was wrong!

Sightings for each species should be totalled and, knowing the area of the block, a density can be computed.

Correction factor for Smaller Species:

Suppose a total of seven blocks were recounted, at a greater intensity. Data are as follows:

	1st count			2nd intensive count		
	Sambar	Chital	BD	Sambar	Chital	BD
Block 1	19	24	7	17	27	11
2	36	32	4	39	40	9
:	:	:	:	:	:	:
etc.	:	:	:	:	:	:
Total	136	234	31	134	268	68

(BD = Barking Deer)

The ratios between the second intensive count and the first count give the correction factors:

$$\text{e.g. Sambar} \quad 132/136 = 0.97$$

$$\text{Chital} \quad 268/224 = 1.2$$

$$\text{Barking Deer} \quad 68/31 = 2.2$$

Note totals for even the largest species are never going to be the same from day to day as animals can be missed, or move in and out of small areas. What we are looking for are significant differences. Perhaps anything greater than a ratio of 0.8 to 1.2 can be thought of as significantly different (This can be checked statistically by several simple tests; comparing means and variances by a 't' test may be the easiest (consult a statistician for details).

If the density from the first count was 0.9 barking deer per sq km, this will be multiplied by the correction factor of 2.2

e.g. $0.9 \times 2.2 = 2.0$ sq km, to give corrected or 'true' density.

Note that the first count data (of 0.9 barking deer per sq km) can be used as an *index of abundance*. There is no need to attempt correction factor unless an absolute figure of abundance is necessary. the index can be used to compare similar areas or different years.

Box 6
Sample Compartment Count Technique:
Melghat Census Data - January 1988

(Total Area=1597.2 sq km : Core Area=308.2 sq km : Buffer Area 1289 sq km)

In January 1988, 74 compartments were selected randomly from both the core zone (25 compartments) and the buffer zone (49 compartments). Selected compartments were then censused by counting teams walking a line transect system with lines 100m apart—a form of line abreast census.

Till date the results have been used simply to calculate an estimated total number of animals in Melghat. However, a slightly more complex statistical analysis can show useful facts. A sample can of course show estimates of precision (as confidence limits) but also for example, the differences between core and buffer zones.

Results

1) Total Numbers (based on 74 samples):

Species	Density/sq km	Confidence limits	Total number	Confidence Limits
Gaur	0.99	± 0.35	1581	± 563
Sambar	0.79	± 0.21	1262	± 335
Barking Deer	0.40	± 0.25	638	± 192
Wild Boar	0.58	± 0.37	926	± 591

2) Density in Core & Buffer Zones:

Species	Core Density	Buffer Density	Significant Difference
Gaur	1.77 ± 0.36	0.59 ± 0.18	Yes (99%)
Sambar	0.93 ± 0.25	0.72 ± 0.11	No, but a possible trend to higher densities in the core

(Other less frequent species not analysed).

3) Density in Compartments With & Without Water Holes

Species	Density with Water	Density Without Water	Significant Difference
		(n = 14)	(n = 60)
Gaur	1.22 ± 0.50	0.94 ± 0.18	No
Sambar	1.21 ± 0.35	0.69 ± 0.11	Yes

Notes

Core/Buffer data are of interest, both gaur and sambar showing higher densities in the core. The data for gaur shows a significant difference (95% probability) in density; that for sambar does not. Traditional knowledge of Melghat suggests that most gaur are in the hills of the core zone in winter. Sambar are less likely to show such major shifts in home range.

Effects of Water. Gaur do not show a significant difference, but sambar do show a difference with water availability, although both species are water dependent. In January however water is not limiting, and so little meaning should be attached to these results. This small note is included to show the importance of sampling design. If the effects of water availability required careful study, then a different time of year should be chosen.

Block Count Census IV : Analysis for the Total Protected Area

A Total Count:

If the whole protected area is being counted in this manner, as may be practical for say large herbivores in Bharatpur of 27 sq km, then the individual block counts are added to give the total number of animals. This total can be divided by the overall area to give the species density for the whole park. Individual block densities should not be averaged as this may be weighted in favour of slightly larger or smaller blocks. Note that no population variance estimate is possible for a total count.

A Sample Count:

a) Without Prior Stratification:

Simply, all separate block densities (corrected if necessary for smaller species), should be summed to give a mean density and confidence limit. This again may be biased in favour of different block sizes, for this become more complex. The interested reader should see Norton-Griffith (1976) in the reference list.

Data may come from 23 separate blocks, as follows, for sambar:

Block	1	2	3	4	—	23	Mean	Variance
Density	11.2	6.9	4.8	16.8	—	6.4	10.4	± 16.3

The variance should be transformed to standard deviation S.D., standard error S.E. and confidence limit C.L. (95%) as follows (but see appendix):

Variance = 16.3, S.D. = $(16.3)^{1/2} = 4.03$, S.E. = $\frac{4.03}{(23)^{1/2}} = 0.84$

Confidence Limits = S.E. x t value = S.E. x 2.07 = ± 1.74

The mean density and confidence limits for the pro-

ected area is thus 10.4 ± 1.74 per sq km. For a protected area of 225 sq km this will give an estimated total number of animals of 2340 ± 390 or between 2730 and 1950 animals.

b) With Prior Stratification:

Procedures are just the same, except they are done for each stratum separately, as below (not the same data as above).

e.g. For chital in three habitats: forest, grassland, woodland. Density ± confidence limits for each stratum, area, and population size data are:

Forest 3.8 ± 1.4 , Area = 45 sq km, No. = 171 ± 63

Grassland 0.9 ± 0.3 , Area = 67 sq km, No. = 60 ± 20

Woodland 14.9 ± 2.4 , Area = 113 sq km, No. = 1684 ± 271

Total = 1915 ± 354

Some Actual Examples:

Variations of these methods have been attempted for rhino in Kaziranga N.P. (Assam) using single teams on elephants counting compartmental blocks. In 1984 a sample count provided reasonable data. Improvements for future counts could include a smaller number of highly trained teams counting sample blocks over several days, plus some double counting to check on data repeatability. The assumption that all rhinos are in the open burnt areas needs to be checked.

The method of counting small blocks, was tested in Dudhwa N.P. (U.P.) in 1985, using teams of four (including an armed guard). The blocks used were compartments or half compartments, upto 2 sq km in size. The area was stratified into predominantly grassland or predominantly forest blocks. Repeating the count of single blocks three times gave consistent results for larger species. Barking Deer were under-counted and data needed correcting.

The method has been used in Panna N.P. and in Bhandhavgarh N.P. (both in M.P.) and details are given in Box 7 and Box 8.

Box 7

Block Counts with Correction Factors

This example comes from Panna National Park in Madhya Pradesh, with census operations organised by Mr. H.S. Pabla. The method has been discussed in the field and in the Institute.

Panna N.P. of 512 sq km was divided into 110 census blocks. These were all counted by groups of 2-3 people in one day, and the operation repeated the next day. Can one team "count" intensively a 5 sq km area of forested hilly terrain in one morning? If 8 sambar were to be seen and 2 missed, this is a 20% error! The Park Director believed there was a good chance of undercounting, and so some units were recounted using 3 or 4 teams.

There was considerable discussion on how big a recount sample (5 was obviously too small), how the sample should be chosen, and should there be several teams in one large sample unit or one team in very much smaller units.

The Correction Factors for common species were calculated as:

$$\frac{\text{Average Number Per Unit on Intensive Count}}{\text{Average Number Per Unit on Initial Count}} = \text{C.F.}$$

There was discussion on further treatment of this factor to compensate for double counting. In the original data set the correction factor was reduced by half. This gave correction factors of:

Sambar	1.36
Nilgai	1.88
Chital	1.16
Gazelle	2.30

Final census figures were:

	Uncorrected	Corrected	Corrected density per sq km
Sambar	389	529	1.05
Nilgai	1163	2187	4.33
Chital	330	383	0.76
Gazelle	716	1647	3.26

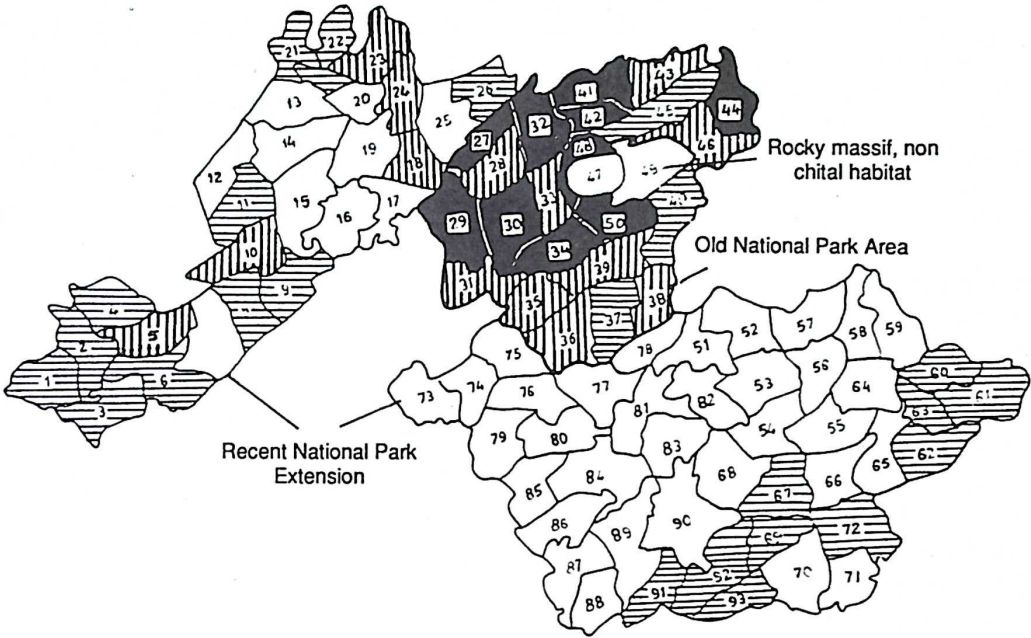
Suggestions were:

- Use intensively small sample units for checking.
- Use one team per unit; use trained teams.
- Justify adhoc correction factors such as 'reduced to half' to avoid double counting.
- Repeat some counts to show level of internal variation.

Box 8
Data Presentation for Total Block Counts
Pattern of Chital Density in Bandhavgarh N.P.

Census was by block counts in 93 sampling units, with a correction factor applied by an intensive second count in a sub sample of 11 units.

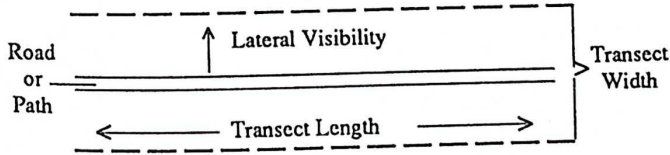
- [white box] = densities of 0-1 per sq km
- [horizontal lines] = densities of 2-6 per sq km
- [vertical lines] = densities of 7-15 per sq km
- [dark grey box] = densities of 16+ per sq km



2.3.2 Vehicle Based Transects or Road Counts

Introduction:

Transects, are long thin sample units covered by a single traverse usually down the centre of the transect. In vehicle counts, the road forms a convenient centre line and the counting transect is a strip of land either side of the road, e.g.



Sample counts give density data; and density "D" (often referred to as estimate of Density i.e. $\hat{D}$) is calculated as number per unit area.
e.g. $\hat{D} = \frac{\text{Number of Animals Seen}}{\text{Transect Area}}$

= $\frac{\text{Number of Animals Seen}}{\text{Transect Length} \times \text{Transect Width}}$

In this equation the number of animals seen is known. This is simple. Care ought to be taken to maximize the chances of seeing animals:- e.g. census crews should maintain silence and avoid disturbance. The transect area should be traversed slowly and a strict watch maintained. (In some cases correction factors may be needed; for example missing fawns or calves in tall grass).

For calculating transect area, the measurement of length is easy. This can be done from a vehicle mileometer (check it!) or from the measurement on a map, or counting paces etc. The calculation of transect width however is difficult, and can require both complex mathematics and making assumptions which may not be met. Two types of width estimators will be discussed, a fixed or closed width transect, and an open or non-fixed width transect. Determination of transect width is one of the most complex topics in modern census methodology. The interested reader is referred to the monograph by Burnham, Anderson and Laake in the bibliography.

Transect Design:

The use of a vehicle pre-supposes the presence of an adequate road or track network in the reserve. An earlier section discussed the problems of roads for census purposes, where the practice of fire-line or view-line cutting along a road greatly changes patterns of animal distribution.

If vehicles are to be used there must be a sufficient track system where roadside conditions are similar to the rest of the reserve. As a general rule there should be 50 km of motorable track for every 100 sq km of study area. Why? - this assumes 25 m wide visibility on each side giving a total width of 50 m. A transect of 50 km and 50 m wide gives 2.5 sq km searched in a 100 sq km, or a sample intensity of 2.5%. Sample intensity should not fall below this, and ideally should be higher. If you assume that animal distribution patterns are random with respect to road sites, and the roads cover adequately the range of habitats in the sample zone, then the network could be repeated in the census interval to increase coverage to 5.0 or 7.5%.

Ideally a transect system should be constructed especially for a census operation. Transects would then be straight, systematically placed and running across any habitat zonations in the stratum. If you have to choose a readymade track, then choose a variety from each habitat. If you can, choose straight roads, with little traffic pressure. Roads should have as little viewline/fireline disturbance as possible.

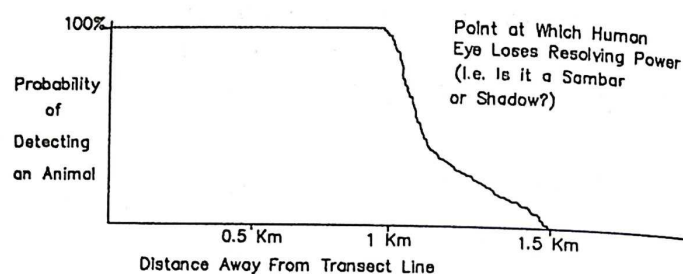
Each transect can form a sample and if there are 10 transects then there are 10 samples with which to estimate the mean. Note a single 20 km transect can be split into two 10 km sample units. If each transect is in very different conditions then variances will be high. In this case treat the whole transect system as one sample and repeat the whole sample several times each census interval. Stratification into different habitat conditions can improve confidence intervals. Longer transects will give lower confidence intervals than shorter transects. Census efficiency will also be determined by the number of sightings along transects. Ten observations along 5 km, will be better than two along 20 km!

The Determination of Transect Width:

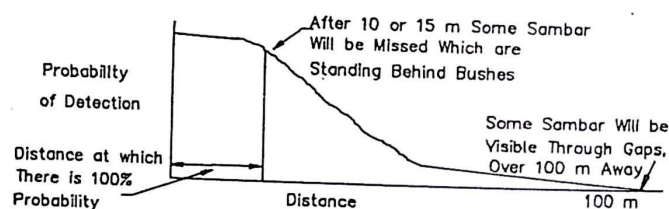
a) Fixed Width Transects:

In open habitats, such as short grassland or semi-arid woodlands, it may be possible to have adequate lateral visibility for a long distance from the transect. It is useful to discuss what adequate lateral visibility is, and how it may change depending on animal and vegetation types.

If there was no obstruction to visibility, a keen-eyed man should see a sambar 1 km or more in distance. A graph of sighting ability would look like this:



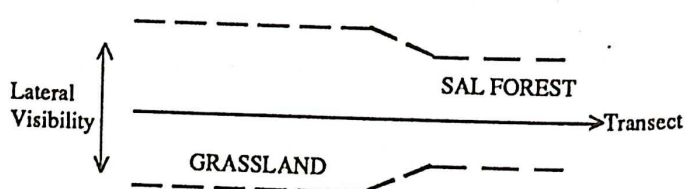
If in these conditions, a transect width of 1 km wide was pre-selected, then no animals would be missed. But, how far can one see in a typical situation in the jungle? Vegetation and topographic features obscure visibility. A graph of sighting ability would look like this:



This can be called a plateau-slope-tail distribution of sighting distances, the plateau being the part where there still is 100% visibility. Obviously this will change; with species of smaller size, or less active behaviour or as vegetation gets denser, the extent of plateau will decrease.

A fixed width transect assumes you are able to estimate and determine what the distance will be at which you get 100% visibility across the transect system. This distance is then the lateral width for each side of the transect. All animal sightings made outside this distance are then ignored. The visibility is *fixed* at this distance.

Note: The minimum distance should be taken from the transect system. But if there is a situation like this:



then stratify, and census and analyse the grassland separately from the sal stratum, using different fixed widths. Otherwise the sal width would have to be used. Note you should not use an average, unless you are certain animal densities are the same in each stratum, which would rarely if ever, be true.

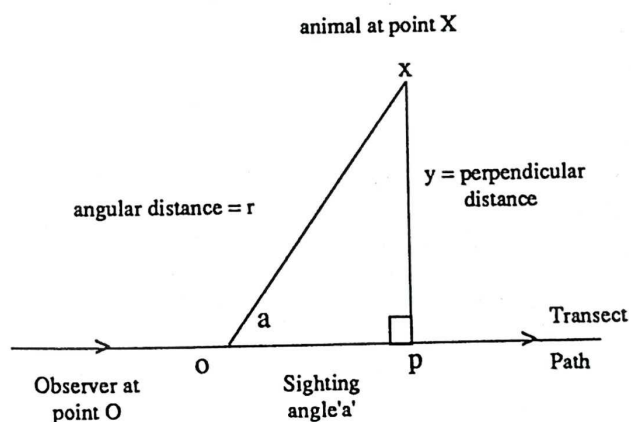
b) Open Width Transects:

Fixed width transects are inefficient in many cases, as sightings will be rejected outside the fixed distance. This may not matter where densities are high; but when dealing with a rare species it can be very inefficient and annoying, to have to ignore the sighting of a herd of gaur as they were 22 m not 20 m away. Bias must not be allowed to creep in and make you include such a sighting.

Open width transects use all observations, and the frequency of distances at which each group of animals is seen is used to estimate an optimum strip width.

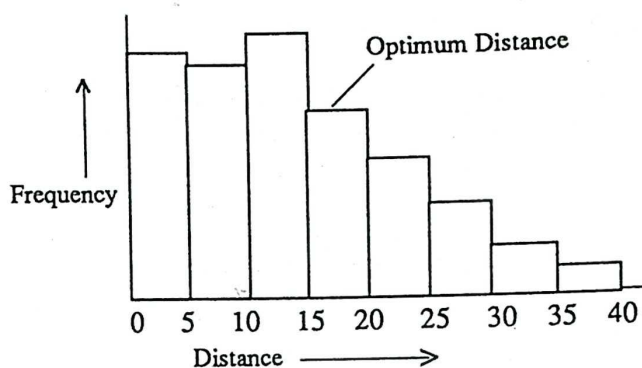
Three techniques may be used: Kelker belts, established formulae, and computer analysis using Fourier Analysis. The latter technique is described separately as section (2.3.4). All techniques use the same trigonometric principles around the sighting of an animal, i.e.

All sightings are recorded and the perpendicular distances from the transect to the animal at point of first sighting is determined (see below for ideas on measurement) as per the diagram:



i) Kelker belt

The frequency of different sighting distance classes (5 m classes are fine) is then plotted below. At least 50 separate distance measures should be used, but the more data available, the better the curve that can be drawn.

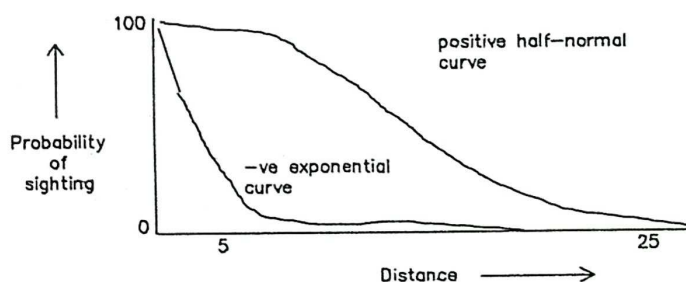


The point where the class levels begin to drop off is then selected as the optimum strip width, and all sightings beyond this point are rejected. Here the width would be 15m. A larger example is shown in Box 9.

ii) Use of a formula:

(The King Census Technique that follows in the next section, is another example of these methods).

If the probability of sighting an animal at increasing distance follows a distinctive mathematical curve, then the average strip width can be calculated from the formula of that curve. Two types of curve are frequently encountered. One is the plateau-slope-tail curve, which resembles the positive-half of a normal distribution. The other curve resembles that of a negative exponential.



The negative exponential type curve results from the case where animals are usually not seen until they are disturbed: e.g. partridge, hares, etc. An animal like this 'freezes' or hides on seeing a person and only moves if the intruder comes too close, when we say it is 'flushed' out of hiding. This means that for example upto 5 m, most animals will be so sighted, but very few at 10 m. There will always be the odd case of some individuals being seen upto say 20 m.

It is important to understand which of these two patterns the census is dealing with:- larger animals which are easily seen, or smaller animals which hide until flushed. The formula to use for each is quite different. Plot a graph of sighting distances frequencies you obtain so as to check! Use atleast 50 sightings to obtain such a curve.

For Flushed Animals:

An estimate of strip width or lateral visibility is approximated by the mean *perpendicular* sighting distance each side of the transect.

$$\text{Density then becomes } D = \frac{n}{L \times 2 \times f y}$$

Where n = number of animals seen on the transect

L = transect length

2 indicates two sides of the transect

f = is a function of y , the mean perpendicular sighting distance

Note: L and Y have to be in the same units, usually kilometres. The value of ' f ', which depends on species behaviour and visibility, is discussed below.

For Larger Animals which are not Flushed:

Strip width is approximated by mean *angular* sighting distance each side of the transect.

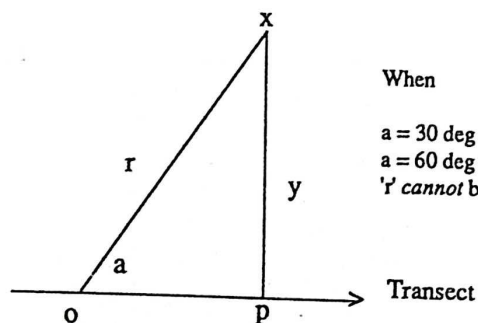
$$\text{Density is then } D = \frac{n}{L \times 2 \times r}$$

Where r is mean angular sighting distance.

This is the basic King Census Formula, which is an efficient and robust estimator; i.e. it can be used for a great variety of animal species and habitats.

Details are given in the following section for walked transects.

Note: " r " cannot equal " y " unless all animals are seen at right angles. In practice most animals are sighted at an angle of from 30 degrees to 60 degrees.



Measurements in the field suggest that for African savanna, large herds of large animals in open conditions will have an average sighting angle of just over 30°. Smaller herds of smaller animals in a wooded environment will have a larger angle. This has been the case in Sariska and Rajaji. When sighting angle is close to 55°, then $f=1.2 y$.

Field Procedures:

i) The vehicle must be used in the most efficient manner to act as a sighting platform. An open jeep is ideal with a crew of four: driver and recorder (both of whom should also observe!) and two standing rear observers. In practice, in dense vegetation, front seat observers see as much or even more than those standing as they will look through, not on top of vegetation! More than 4 becomes uncomfortable, people talk and lose concentration. Trained observers should be used.

ii) A speed of 20 km per hour is optimum in terms of visibility and efficiency. With stops to check and count and record observations this means that a maximum of some 10-12 km can be covered in one hour. Transect counting is a slow job! The ideal time is early morning or late afternoon when animals are more active and hence more will be seen.

iii) Sighting distances have to be measured. Even if a fixed width transect of a preset 20 m is chosen, it will be necessary to check animals seen at 16, 17, 18, 19, 20, 21, 22, 23, 24 metres, to see if they are more or less than 20 m. Guess work leads to errors.

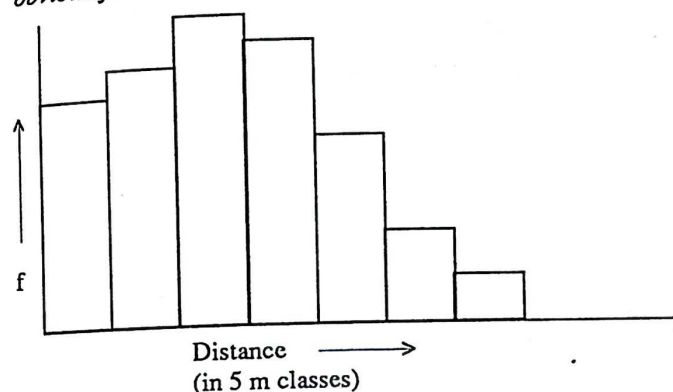
Estimating distances by eye is not easy, people do improve with practice. Test yourself frequently by estimating and then measuring. Use a well known distance as a standard, e.g. a cricket pitch. Distances can be estimated by range finder, but they are not easy to use. The safest is to pace out distances. Walk normally and know your average pace length. Most people have a pace of about 0.7 m. Remember if you are consistently wrong by 10% in estimation (and distinguishing 45 from 50 m is not easy) then there will be a 10% error in the final census total!

From a vehicle it is not easy to estimate angular distance, which is *from the point of first sighting* to the animal. Normally a vehicle has gone some 10-20 or even 30 m past such a point by the time it stops. The observer thinks he sees an animal, he looks again and confirms it, he shouts to the driver, who then stops! For this reason it is more practical to use perpendicular sighting distances than angular sighting distances when in a vehicle.

Note: Sighting distances should be to the approximate centre of the group of animals that have been sighted. The location of a sighted animal should be noted immediately in case animals move away.

In many cases there will be dead space between the observer in the vehicle to the edge of the road surface and perhaps a ditch or mound or culvert or dust covered "dead" vegetation. This may be 5 m and is unlikely to be used by animals. Distance measurement should be from the end of such dead space to the animal. Inclusion of this dead space frequently leads to a strange dip in the first class of a graph of sighting distance frequencies; e.g.

Lower number in first one or two classes which suggests that there is a lower probability of sighting nearby animals, which is obviously not so, or animals avoid area near the transect line.



If such a dip persists even when dead space is not measured - do not worry. It will not materially affect your estimates. The dip may be due to non-habituated animals moving away from a road when they hear a vehicle approaching.

iv) Data recording. A proper format should be used and prepared before hand, e.g.:

Area: Sariska: Transect: Main Gate to Kalighati. 21-11-86					
Observer P. Sharma. Time Start 0610. Time Finish 0814					
Obs. No.	Km Seg-ment	Spe-cies	No.	P. Dist-ance (m)	Notes
1	1-2	N	2	10	Eat
2	1-2	N	1	6	Ziz.maur.
3	2-3	S	3	12	All males.
4	3-4	C	17	30	Same as yesterday

The noting of kilometre segment allows a further level of analysis of animal distribution. It is not essential for assessing density.

Data Analysis:

For each stratum and each season a single mean value

as an estimate of lateral sighting distance should be used for each species. Calculate the mean sighting distance from all observations of that species in that season. A minimum of 50 distance measurements should be aimed at for most species.

Simply, the total transect length and the total number of animals sighted during that transect coverage are counted; then:

$$\text{Density} = \frac{n}{L \times 2 \times f_y} \text{ or } \frac{n}{L \times 2 \times r} \text{ as described earlier}$$

Use a suitable function of 'y'. In dense bush land or forest for large herbivores, use 1.2 y

If confidence limits are to be calculated, then a decision as to which is the sample unit must be made. Each separate transect, or the whole network? Each unit should be roughly the same size, otherwise a weighing variance factor will have to be used (see examples in Norton-Griffiths 1976).

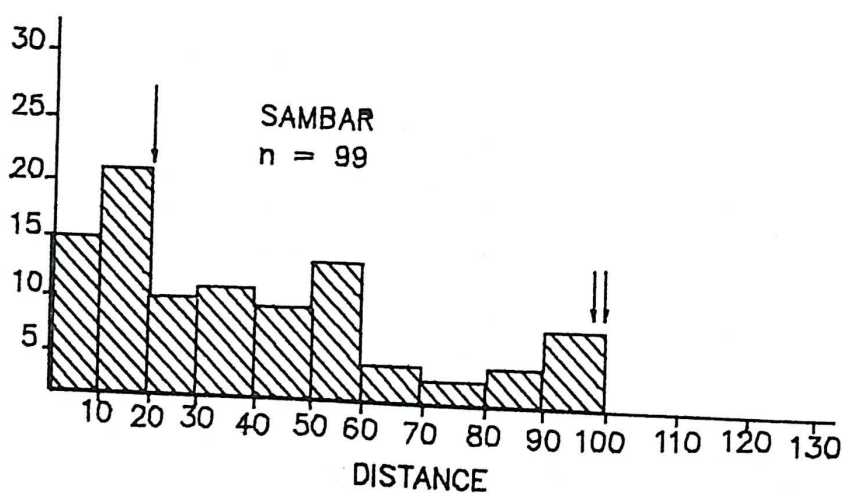
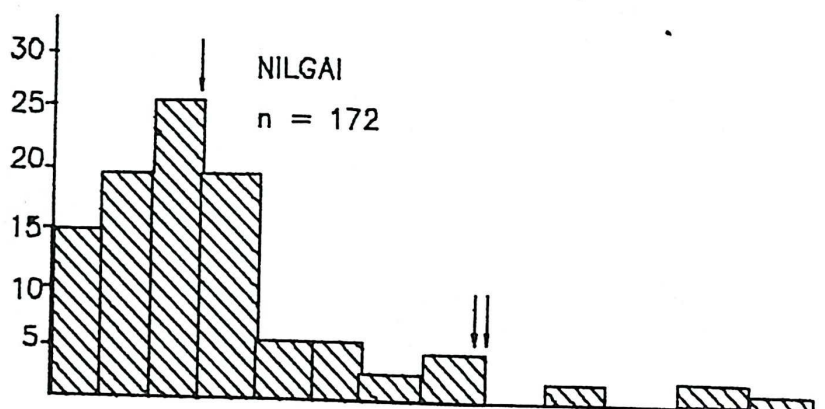
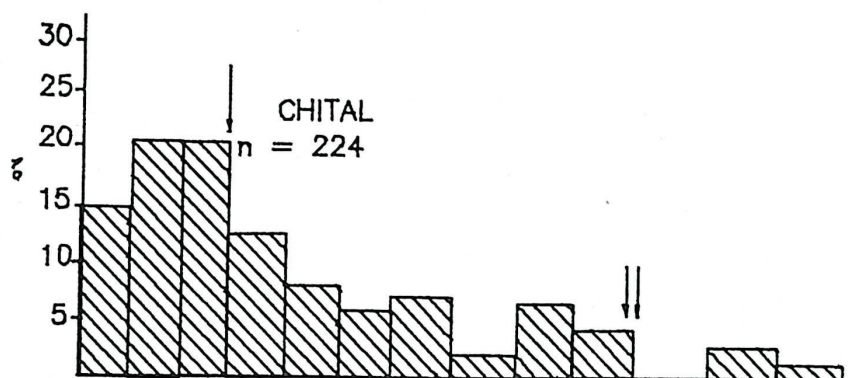
Treat the density from each sample unit as a sample measurement. Calculate the mean and variance and confidence limits in a normal way.

Note: 1) What has been described is a very simple analytical procedure. Ideally the variability in mean sighting distance estimation should be taken into account, different transect lengths accounted for, and a covariance factor established etc. If this level of refinement is needed, consult a statistician.

2) The mathematical basis behind the King census estimator is obscure. Modern scientific transect usage involves more complicated sight distance estimation procedures using Fourier analysis and computers (see section 2.3.4.).

3) Time of day is important for efficiency of sightings. Morning and evening drives will yield more observations per kilometre travelled. This does not mean that densities will change. Fewer animals will be seen at shorter sighting distances in the middle of the day as animals will be at rest and in shade. As the number of observations affects the variance of the census estimate, it is important to choose optimal timings.

Box 9
Sighting Distance Frequency Distributions (%)
 (Pendicular Distances) Data from Sariska 1984-86.



- 1) Visual examination of data to choose best distance estimator using a Kelker Belt technique.*
- 2) Note few sightings in first 10 m segment.
- 3) Truncated distance parameters for Fourier analysis would be at:**

Box10

Example of a Vehicle Based Transect Count: Gazelle

In July 1989 a brief census was undertaken of Indian Gazelle in a relatively homogenous agricultural area of 49 km² near Jodhpur in Rajasthan.

1. 90 animals were sighted in 29 groups (mean group size of 3.1) along a total of 34.3 km of track, divided into 8 sections.
2. Mean perpendicular sighting distance was 80.4m (± 20.1 as 95% confidence limit).
3. Approximate average sighting angle was 45°, giving a coefficient of 1.4 for use in a King Census formula; i.e.

$$\text{Density} = \frac{\text{Number}}{\text{Area}} = \frac{\text{Number of Animals}}{\text{Transect Length} \times 2 \times \text{Mean Perp. Dist.} \times \text{Coeff.}}$$

$$\hat{D} = \frac{90}{34.3 \times 2 \times 0.0804 \times 1.4} = \frac{90}{7.7} = 11.7/\text{sq km}$$

4. Sampling proportion was area sampled/total area = 15.8%.
5. In 49 sq km there would be 573 gazelle.
6. Use of the 8 sections allowed an estimate of confidence level around the estimated density; this was 11.7% or $\pm 4.8/\text{sq km}$, but further sampling would have reduced this figure substantially.

2.3.3 The King Census Technique or "Foot Counts"

Introduction:

The King Census Technique has the advantage of being a simple, flexible and relatively unbiased method of determining population density. It is one of a family of transect methods, in this case using open width transects and a calculated sighting distance estimator for width. The rationale behind these methods is discussed in the preceding section, "Vehicle Based Transects or Road Counts", which should be read in conjunction with this technique.

The technique as described here is designed for walking transects, and so can be used in any form of terrain or vegetation type (except perhaps mountain areas where great visibility across valleys precludes measuring lateral distances), and for determining the density of any animal that does not rely on hiding to avoid detection. Trees, termite

mounds, large birds etc. can also be censused by this technique.

This description presupposes that the reader has completed the previous section.

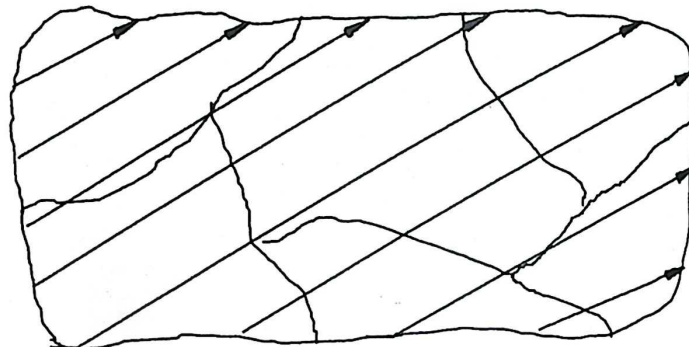
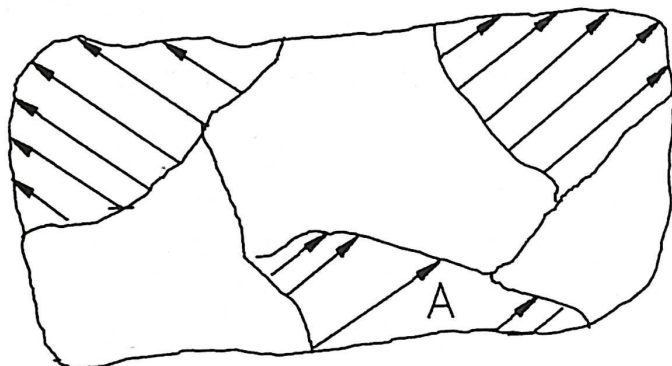
Census Design:

A transect network should be designed to cover each stratum in the protected area. Transects can be placed randomly or systematically within the stratum. For low intensity coverage, a systematic grid of transects ensures better coverage of all areas. When a stratum is large, it may be covered by two-stage sampling. Choose a random sample of blocks from all blocks in the stratum, and run transects within these sample blocks.

A walked transect design needs known start points and end points where census teams can be dropped and collected by vehicle, if the design is to be used efficiently! Possible designs are shown in the diagrams.

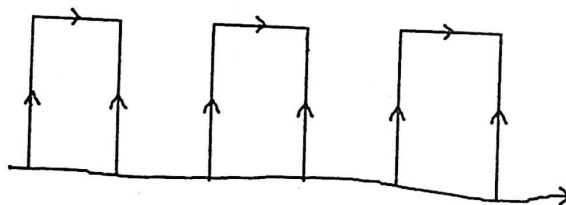
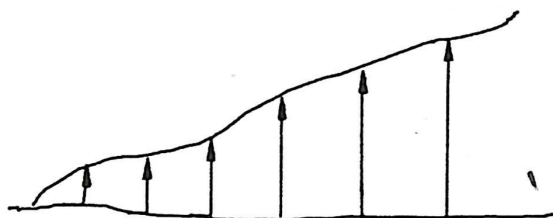
A selection of blocks are sampled intensively within an overall large homogenous stratum. Note one block shows an example of a random grid, others systematic.

The whole area may be covered systematically. This may be difficult in terms of getting to start and finish points.

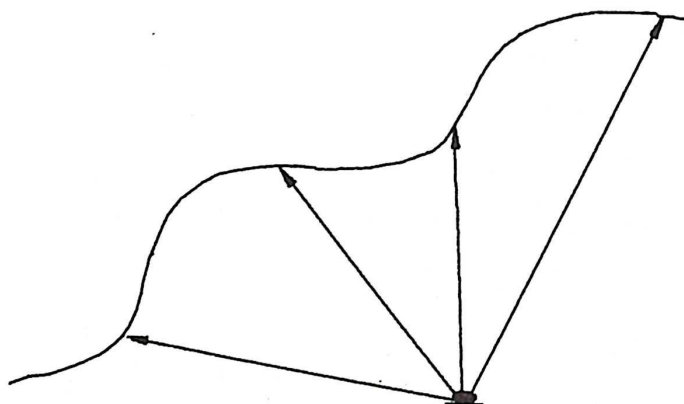


A transect grid covering an area between two tracks

A transect grid where there is only one track.



A star like grid from one start point to a road network.



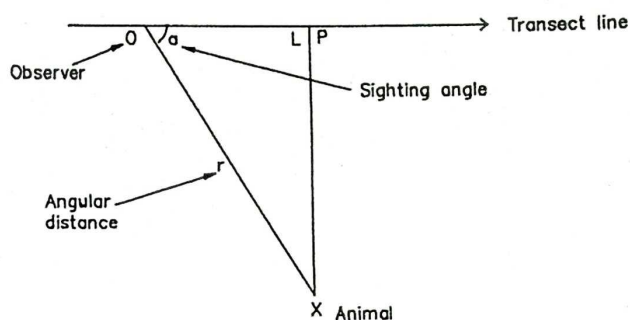
Once the sampling areas are chosen, plan the transect pattern. Using five transects at a time usually means a total field census crew of ten. Transects should start on an accessible base line e.g. a road, and preferably cut across minor topography (streams, valleys, slopes and ridges) rather than run parallel to them. Transects should be far enough apart to prevent interference (0.5 km in forest, 1 km in open areas as a minimum).

Ten km per day is probably a maximum in easy conditions, less in difficult terrain or with very dense populations. Transects should be run in the early morning. Evening transects can be dangerous, if people get lost and have to return in the dark.

Each team of two or three people needs a sketch map with their route marked, a compass, data clip board and binoculars. Where essential one person should be armed. The team walks along their transect on a pre-determined compass bearing looking for animals on both sides. One person counts the number of paces traversed (an average pace = 0.7 m but check!) which gives the actual distance covered and allows the location of each sighting to be noted if so desired. Alternatively actual distance covered can come from a large scale topo-map; but use pacing as a check.

On sighting an animal, the group is counted and their position noted. The pace number at sighting is recorded. The distance from the point of first sighting to the centre of the observed group is estimated or paced (see previous technique for details). An exercise in trigonometry can help estimate the

angular distance, which is useful when long distances have to be paced.



The pace number along the transect at O is noted, and the compass used to calculate the bearing to the animal at X which allows calculation of 'a'. The census team then walk on along the transect to the point P perpendicular to the animal's first position. The pace number along the transect at P is noted. The distance OP can now be determined. Knowing OP and the angle a (the difference between compass bearings for transect and to animal) the hypotenuse of the right angled triangle (or 'r') can now be calculated by trigonometry e.g.

$$r = \frac{OP}{\cosine 'a'}$$

As measuring angles and counting paces is within the abilities of forester level staff, it is recommended that census staff do this always when 'r' is likely to be over 20 m or when counting paces along 'r' disturbs animals further along the transect.

The value of such observations reinforces the need to have a specially trained census team rather than all the staff of a protected area.

A proforma should be completed by each census team e.g.
Area Block 3, Sariska. Transect 5, Bearing 090 deg. 22-11-86
Observer A. Singh Start Time 0620 Finish Time 0929 Finishing Pace 9250

Obs. No.	Pace	Species	No.	Angular Dist. Estimate (m)	Bearing	Angle	2nd pace	O-P	Calculated Angular distance	Notes
1	624	Sam	1	16	120	*	640	*	*	By pool
2	957	Sam	4	10	145		1010			F
3	2041	BD	1	10	150		2050			-
4	5960	Lan	12	30	110		6100			-

etc.

* These columns should be completed by the census organiser after the transect proformas have been handed in.
e.g. for Observation 1.

- Angle = Difference between Transect Bearing and Animal Bearing = 30 deg
 OP = Difference between Pace and 2nd Pace
 = 16 paces.

$$\text{Calculated Angular Distance} = \frac{\text{OP}}{\text{Cosine } 30} = \frac{16}{0.866} = 18.5 \text{ paces}$$

With a pace equal to 0.8 m, the calculated distance is thus 14.8 m.

It is always useful to estimate 'r' as well as calculate 'r' from trigonometry. Measurements can go wrong. When 'a' is very large (close to 90°) then big errors can creep into determination of "r".

On completion of the transect the census organiser should interview each census team to discuss routes and sightings. Proformas should be checked.

Data Analysis:

Data on sighting distances for each species should be compiled from all transects within each stratum and a single mean angular sight distance for each species calculated - "r".

For simple calculations, all transect data should be summed, giving an overall transect length (L) and total number of animals of each species sighted.

Density is then calculated as:

$$D = \frac{n}{L \times r \times 2}$$

Where n = total number of animals sighted and the figure 2 is for each side of the transect.

Calculation of confidence intervals requires a decision as to what constitutes a sample unit - each separate transect or a number of nearby transects in one block. The sampling problem is that for short transects with low densities of many species, there will be great variation between transects. By combining adjacent transects into one sample, some of this variation will be reduced, but so will sample size.

The preceding discussion and the suggested proforma may look daunting for a forest officer wishing to use a team of wildlife subordinate staff.

This may not be as difficult as first thought, because:

- 1) Distances covered may be determined from maps,
- 2) Angular sight distances for a species in a habitat type may be determined from a number of observations by the officer and his average value used for the census by junior staff.

This means that field staff only have to walk from A to B and count animals seen!

Box 11 Example of a King Census Foot Transect: Nilgai in Sariska

Nilgai Census: Sariska Valley Scrubland, Nov. '86.

Walked Transects, King Census Technique, using Radial (Angular) Distance Measurements from Line of Travel.

9 Transects, averaging 3.4 km in length, East West across valley using Tarmac central road as a base line. The whole area is some 10.5 sq km

DATA SET

No.	Length (km)	No. Group	No. Animals	Mean Angular Dist. (m)	Estm. of Grp. Density per sq km	Overall
1	3.5	5	10	78	13.64	42 groups seen on a total of 30.2 km at an average of 52.3m $D = \frac{n}{L \times 2 \times \text{mean distance}}$ $D = \frac{42}{30.2 \times 2 \times 0.0523}$ $D = 13.30 \text{ sq km}$
2	2.8	4	6	70	13.66	
3	2.5	7	7	59	26.76	
4	4.4	2	2	32	4.35	
5	3.4	8	20	52	22.49	
6	3.8	5	7	28	12.58	
7	2.5	3	5	65	11.47	
8	3.6	3	6	32	7.97	
9	3.7	5	15	27	12.92	
	30.2 kms.	42	78	Mean (weighted from all data)	13.52	Mean group size is $78/42 = 1.86$ Animal density = 25.15 per km ²

1. The individual transect densities have been calculated using the overall mean sight distance of 52.3m. Individual transect data allow the calculation of a confidence interval around the overall mean density = 25.15 ± 8.5 (95% limits) of animals/km².
2. 1985 data for the same area had an average of 50.3m sight distances and 47 animals were sighted over a 23 km transect grid. This gives a density of 23.3 nilgai per sq km, not significantly different from 1986.
3. In 1986 a total area of $29.7 \times 2 \times 0.0523 = 3.1$ sq km was searched = 29.6% sample intensity. Note that a high intensity but few actual samples (9) gives a large confidence interval. A better confidence limit would need 20 transects.
4. 25.1 nilgai per sq km in a 10.5 sq km area = 264 nilgai.

2.3.4 The Fourier Series Estimator

This is the method of choice for unbiased statistically robust analysis of data which have good measurements of perpendicular distance "y". Fourier is the name given to a mathematical method which analyses sine waves:



The pattern of distribution of perpendicular distances approximates part of a sine wave. The technique was developed by Burnham, Anderson & Lake (see reference section) and their 1980 monograph is still the standard text for census analysis.

The method involves complicated mathematics, and lengthy calculations, and is very tedious. However, if a standard IBM compatible PC computer is available, then analysis can be undertaken simply by using the Programme 'TRANSECT' or derivatives. (These are available at WII, Centre for Ecological Sciences at Indian Institute of Science, Bangalore; BNHS in Bombay; School of Ecology at Pondicherry etc. or from Burnham in USA). Even though analysis is simplified by computerisation, the interested user should seek statistical advice as to the suitability of data for analysis and the interpretation of results. Sometimes different analyses may be more appropriate, such as a "polynomial" technique; which is also available on some "Transect" programmes, or on standard computer statistical packages.

Fourier Analysis Input:

All species have to be analysed separately; but combine all the transects from any one census period.

The following data inputs are required:

1. A list of all observations of perpendicular distances.
2. Number of such distance measurements. This is "n".
3. Total distance travelled from all transects used in the analysis. This is "L".
4. Choice of the last perpendicular distance to be included, "truncated distance". This will usually be the farthest distance recorded, but if there are one or more outlier data points, these can be excluded. For example if most sightings are below 50m, and there is one sighting at 75m and one at 95m, exclude these two. Truncated distance would be 50m. This is "w".

Fourier Analysis and Output:

Note the symbol $\hat{}$ indicates an estimated value. Estimated Density $\hat{D}$ is calculated from:

$$\hat{D} = \frac{\hat{f}(0)}{2L} \quad \text{where } \hat{f}(0) \text{ is } \frac{1}{a}$$

$\hat{a}$ can be explained as the *proportion of animals seen* out of the *total animals present* in the area, upto the maximum distance from the transect. This maximum distance is "w" and is input parameter 4 described above.

The computer calculates $\hat{f}(0)$ as

$$\frac{1}{w} + \sum_{k=1}^m a_k$$

$$\text{and } a_k = \frac{2}{nw} \sum_{i=1}^{2n} \cos(k)(x_i \sqrt{w}).$$

Where n is number of data points.

x_i is the i th distance measure

k is a constant 1,2,3 etc.

m is the number of such constant terms used up to a stopping rule, where

$$a_{m+1} < \frac{1}{w} \left(\frac{2}{n+1} \right)^{0.5}$$

Typically 2 or 3 terms would be used: i.e.

a_1, a_2 and a_3 . These are summed to give the estimated value $\hat{f}(0)$.

The computer also calculates the variance of $\hat{f}(0)$.

Given $\hat{f}(0)$, n and L, it is simple to calculate the estimated Density $\hat{D}$.

The variance of the density estimate:

$$\text{Var } \hat{D} = \hat{D}^2 \left(\frac{1}{n} + \frac{\text{var}(\hat{f}(0))}{\hat{f}(0)^2} \right)$$

Computerised Print out

(This obviously depends on which programme is used!). A common version uses this form:

Parameter	Point Estimate	Std. Err.	% Coeff. variation	95% conf. internal
$\hat{f}(0)$	0.04348	0	0	0
$\hat{D}$	3.382	0.904	26.7	1.610-5.153

The estimate of density is 3.382, in this case birds per hectare.

Some programmes may give values for a_1 , a_2 , etc. terms used in the programme.

A useful discussion on the Fourier technique and a worked example is given in Brockelman and Ali (1987), see reference list.

2.4 MISCELLANEOUS

This section outlines four methods not easily categorised above. One has already been referred to, the "total count" of an entire area. Two are similar in that they are based on proportions. One, the "ratio method" compares an unknown to a known population, and the other compares proportions from two time periods. Both methods can sometimes be used in wildlife areas. The fourth is aerial survey.

The section also describes techniques of value for survey and reconnaissance, and techniques of use in special situations such as the Himalayas and in Tropical Evergreen Forest. Techniques for use with the crocodilians, primates, birds and livestock are also included here.

2.4.1 Census of Large Mammals Using a Ratio Method

Introduction:

The objective of this method is to calculate a population size for one species, where accurate data exist for a second species of similar size and ecology. It frequently happens that wildlife managers have relatively accurate data on the population size of one particular species using a specific area. An example may be numbers of permitted cattle in a forest block. Knowing this population size, it is possible to estimate population size for other similar sized animals in the same area, e.g. nilgai. Other examples would be a known population of a diurnal species e.g. chital, where regular censuses take place, and a nocturnal species such as wild boar which is less well censused; or a common species e.g. barking deer, and a less common species e.g. four horned antelope, which is more difficult to census.

Methods:

The area is crossed by vehicle or foot and all animals of

both the target and the known species are counted. Ideally representative areas of all habitats in the block would be visited, giving a coverage of at least 10% of the area, or more if populations are very small.

Assume there is a population of 600 cattle in the block, and the survey shows 100 cattle and 25 nilgai. Nilgai population size would be:

$$\frac{\text{Total No. Nilgai}}{\text{Total No. Cattle}} = \frac{\text{Sample No. of Nilgai}}{\text{Sample No. of Cattle}} \quad \text{or} \quad \frac{N}{600} = \frac{25}{100} \quad \text{and } N = 150$$

Note the method would not be valid for animals such as sambar as the assumption of similar habitat preference would not hold true. The method would not be valid for animals such as chital as the sightability of the smaller chital will be much less than for the larger cattle.

Cattle should be dispersed in the block, not concentrated in one huge herd !

Another example would be:

An area has a population of 1500 chital as shown by frequent census data. A months records of traversing forest roads at night with a spot light show 250 chital and 200 wild boar.

$$\frac{?}{1500} = \frac{200}{250} = 1200 \text{ wild boar}$$

2.4.2 Sight and Resight Methods

Introduction:

An enormous scientific literature has developed over the methodologies of population analysis based on the capture, marking and recapture of animals, usually smaller mammals. For large mammals this has been adapted to a sight, recognise and resight methodology.

The method works on simple proportions. If out of a population of animals you trap, mark and release 20, and then collect another sample of 20 and find 5 marked, you can calculate the total population size as:

$$\frac{\text{Number Initially Marked}}{\text{Total Population Size}} = \frac{\text{Number Found Marked in Second Sample}}{\text{Total Number of Second Sample}}$$

$$\frac{20}{x} = \frac{5}{20}$$

$$\text{and } x = 80$$

Similarly, if you initially see and recognise 20 animals (photo identify, stripe patterns, tusk/ear shape) and then go out again and see another sample of 20 out of which 5 you have previously recognised, you can make the same calculation. For details of such capture techniques the reader is referred to books by Seber and Caughley in the bibliography, section 4.

The Method in Practice:

There are obviously a large number of assumptions that have to be made. These concern the sampling operation, i.e., if you retrap in exactly the same locations will you bias results?, and the time frame, if you do the census over a long time period, then what about births, deaths and loss of marks or recognition features?

In Indian wildlife science we will be concerned with methods based on *sight and resighting* of larger mammals, rarely with actual trapping. Examples of procedures for the former are given in more detail.

1) For some animals it is possible to recognise individuals by facial or coat markings etc. Examples include lions by whisker dots on upper lips, tigers by stripe patterns, rhinoceros by horn, ear and scar patterns, elephant by ear notches etc. Sketches, photographs and descriptions in an identity file are essential for accurate recognition of individuals.

This method can be used to identify, and so count, *all* animals in a population. This can be done for large easily found animals in a relatively small area. Example could include rhino in Chitwan N.P., Nepal, tiger in Ranthambhore N.P., Rajasthan, and elephant in smaller isolated populations.

2) With larger populations, or those scattered over a larger area, then samples may be used.

For example: in Gir, suppose over a 1 month period, traversing all road systems several times, a total of 75 lions were seen and identified. In a second 1 month period a total of 80 lions were seen and identified which included 40 lions previously recorded and 40 which were new.

$$\frac{75}{x} = \frac{40}{80} \quad x = 150 \text{ lions population estimate.}$$

What assumptions are made?

Firstly, over the 2 month period births and deaths are negligible. Secondly, no mistake is made in recognition. Thirdly, sampling effort is not biased.

e.g., if during the first month a remote area was visited once, but in the second month, it was visited four times, one would expect a greater proportion of unknowns. We know that most lions are fairly sedentary, i.e. remain within fixed home ranges; they do not disperse randomly over the whole area. Therefore sampling inputs must be large enough to achieve a random coverage on each occasion, or be exactly the same in each case.

2.4.3 Total Counts

Introduction:

Section 2.2.3 discussed the total counting of small sampling units or blocks. The total count of a large area is similar except that problems are greatly magnified. When planning a census operation the decision must be taken about whether to do sample or total counts. It was suggested that sample counting may be preferable, except in cases where the animal to be censused is large and easily visible, and the total area relatively small. The longer the time period taken to do the count, the greater the chances of under counting or double counting. The more people that are used the greater will be the level of disturbance and the probabilities of overlapping, double counting or missing areas. It was stressed that total counts do not have the advantage of sample statistics to give measures of precision of the estimate.

If, after carefully considering all drawbacks, it is still thought that a total count is valuable, in what way should it be performed?

Procedures:

The operation must be planned so as to cause least disturbance and to ensure that there is the minimum of overlap problems. The census must be completed in the shortest time period possible. It is important therefore that all participants be thoroughly briefed, provided with maps, and preferably given prior training including familiarisation of the area.

Key species for the census should be chosen and the census routes and inter-observer distances fixed for these species in the prevailing conditions.

Field procedures will be the same as those described under block count censuses, although blocks will be contiguous. Prior planning might be able to divide up large areas into homogenous parts to be counted in one day - e.g. using barriers such as rivers or watershed ridges to demarcate zones.

Debriefing observers is of importance. This can give ideas on areas missed or of double counting.

The Result:

How much reliability can you attach to the result? It is

not possible to tell as it is a function of census design, observer ability and conscientiousness, terrain difficulty and animal shyness.

One clue as to reliability is to repeat the census, or a major part of it, immediately. An immediate recount means there is no chance of conditions changing - birth season, movement, increased mortality etc., before the next census.

If the two counts are similar then the result will certainly have value as an index of population size. If they are not similar, (i.e. not within 20% of each other) then the result is of no value.

But, there is *no easy way* of knowing how accurate the result is!

Note: Once that you have eliminated double counting, if you then repeat a total count three times or part of the whole is counted three times you accept the *largest*, not the *mean*, as the best estimate.

When all individual blocks are counted more than once, it is the largest overall daily total that is accepted, not the total of the separate largest estimate for each block

A bounded count estimator may be of value in suggesting a best estimate of total numbers, using the differences between at least *four* counts to suggest the real total. This is discussed in Appendix 5.2.

2.4.4. Aerial Survey and Census

Introduction:

Aerial survey and population monitoring is the census technique of choice of many parts of the world including east, south and west Africa, Arabia, Australia and many regions of the Americas. Techniques have now achieved considerable sophistication and allow the objective quantitative recording of data on habitats, animals and socio-economic factors. These data not only give abundance but also spatial and temporal patterns of abundance, with statistical confidence limits. In India there has been no determined attempt to show if the techniques can be used efficiently. Many people believe that the denser vegetation cover precludes useful aerial observation. Stracey however advocated experimentation in India in the 1960s, as did Dharmakumarsinhji! Such experimentation has not been done.

Aerial Survey Possibility in India:

Much of western India does not have a dense tree cover, e.g. Kutch and Rajasthan. The flood plains of the Ganges and Brahmaputra valleys have wildlife populations in open grasslands which are visible after grass burning. The trans-Hima-

layas allow relatively easy aerial observation of medium and large sized animals. Dugongs can be censused in coastal waters. Much of drier Peninsula India can be surveyed in the drier months when many trees are leafless. So claims that the technique is of limited value are not really true.

Survey to be done properly requires considerable pre-flight training of both pilot and observers. Careful attention must be paid to sampling design and survey objectives.

Equipment:

A high-wing single engined monoplane is ideal e.g. a Cessna 172, 180, 182 etc. Most censuses are conducted between 200 and 600 ft. above ground level, and speeds between 70 and 120 m.p.h.. Safety is an important factor and flying should not be too low or slow.

The pilot should fly and navigate, NOT observe. Therefore, for maximum efficiency there should be two or three observers, to cover both sides of the aircraft flight path. However, ultra light or light aircraft with pilot only or only one observer, can often use spiral search patterns within blocks rather than flying long transects, to equal advantage.

All wildlifers should take any opportunity they can to view their areas from the air. However, if anybody wishes to attempt aerial survey, census, or low level photography, we strongly recommend that they contact people with expertise for definite advice, and consult the text books by Clarke and Norton-Griffiths' listed in section 4.

2.4.5 Reconnaissance and Survey

Introduction:

For many of the remoter areas and smaller wildlife species of India we do not have even rudimentary ideas of animal population abundance, nor do we have established techniques for determination of such abundance. The Himalayas and the closed evergreen forest systems are immediate examples. There is no data set which suggests the order of magnitude of densities for ibex, bharal, tahr, Tibetan Ass, takin, brown bear, wolf, snowcock, etc. in the mountains, or clouded leopard, binturong, pheasants, gibbon, or even sambar in the evergreen forests of North Eastern India. The denser forests of the Western Ghats provide equal problems, for example how to census tiger in Periyar.

What is required is a period of rapid survey to establish base-line knowledge on distribution and coarse scales of abundance for specific locations. How to do such survey is the object of this section.

Survey and Maps:

Survey must be location precise, i.e. this ridge, this

nallah, this forest patch. This requires the use of good topographic maps, of sufficient accuracy from which areas can be measured.

Field Work Capability:

Survey of remote & difficult areas requires adequate logistical support:

Mountain equipment and suitable clothing; perhaps armed escort in the forest, local guides, much prior planning and organisation, provision of food supplies, line of communication are all essential. Such arduous work requires interest and motivation. It also needs the input of senior officer/staff.

Distribution Survey:

This is the simplest level of operation, but even so we have very inadequate data for many species. It consists of establishing presence/ absence of a species in a particular area. The areas can be administrative districts or tehsils, forest divisions, ranges or blocks, degree squares or quarter degree squares (i.e. the area of a 1:50,000 map sheet), 10 km grids, 1 km grids, etc. (Grid squares are discussed in section 2.1.1.).

Information on presence-absence in the grid square can come from many sources, the surveyor should clearly distinguish between past information "it used to be here" and present information, "it is here now". The surveyor should start by interviewing knowledgeable people and noting probable localities. These, or a proportion of these, should then be checked in person or using trusted staff.

A grid map for species prese could then be like this :

A	A	O	O
A	A	R	C
O	R	C	C
?	?	C	C

A = Absent
 ? = No information available
 O = Old record now absent
 R = Reported but not confirmed.
 C = Confirmed

Abundance Survey:

Several possibilities exist for including measures of abundance in a preliminary survey.

Firstly, a qualitative or subjective estimate of abundance in each grid (section 2.1.1); this is based on experience of

the species and the area.

Secondly, choosing a number of sample grids and undertaking block counts or transect counts as described in sections 2.3.1 and 2.3.3. This is based on actual sightings.

Thirdly, using an index as to presence, dung, track, calls etc.

2.4.6 Census Operations in the Himalayas

In some cases the nature of the terrain, and the ecology and behaviour of the species, mean that efficient census by the methods discussed in this manual is not possible. Much of the higher Himalayas would fall into this category where extremely steep and rugged terrain and generally very low densities of large mammals, makes census very difficult. This section puts forward some ideas on how simple estimates of abundance may be obtained.

Recording Presence: Absence Data:

The use of 1 : 50,000 topo-sheets or other large scale maps can allow accurate recording of species presence based on actual sightings, dung identification, or reports/records from local people, forest staff etc.. Records can be for grid squares; use 2km x2km for detailed survey, 5km x 5km for a coarse rapid survey. Note that smaller and smaller grids can be used as data accumulates over a number of years. Records could also be for administrative units - blocks, compartments; or for natural units such as drainage basins, hill systems, grazing areas etc. See sections 2.1.1 and 2.4.5.

Distribution maps allow the stratification of a large mountainous protected area into areas which could later be sampled more intensively. Blocks with much positive information could be sampled more intensively than those with only sporadic sightings. Maps help in planning extrapolation, for calculating population totals. If for example, you know that serow have been recorded for 20% of the blocks in Kedarnath W.L.S, and that you know from more detailed research that typical serow density is 1-2 sq km then you can make meaningful guesses at serow population size.

Obtaining Information on Species Presence:

Local knowledge provides a useful starting point. If a past shikari says tahr are found at a certain site, then this should be checked, maybe initially by a guard, later by a senior staff member.

High hills and ridges allow the scanning of adjacent visible areas for wildlife. Topographic maps allow the exact plotting of areas so searched. You may need to scan a hill slope with a spotting telescope for a full day or for the favoured part of the day, i.e. early morning for feeding, or afternoon for basking. Nilgiri tahr in many protected areas in Kerala were successfully sampled in this way in 1987.

Evidences such as dung or tracks can indicate the presence of a species in a particular area, and can be mapped as positive evidence, especially where signs are distinctive, such as musk deer.

Detailed census of small areas:

Several techniques could be tried, for example:

i) Drive or block counts. This should be done as silently as possible; use edge observers who are placed at vantage points to observe animals moving out of the census block. Blocks will usually be small, and many may be needed. Note that the direction of movement should be chosen to drive animals towards the edge observers. This method was used extensively for musk deer in Kedarnath WLS, by M. Green.

ii) Recognition of herds. On any one cliff face there is likely to be only one group of tahr or ibex for example, which may be recognisable by sex and age composition or individual peculiarities. Similarly individual bear or argali or other larger distinctive animals may be recognised and mapped in particular locations.

iii) Relative abundance indices could come from dung counts, or number of calls or sightings per hour searched etc. See the relevant sections of this manual for details.

iv) Appendix 5.4 gives detailed census methodology sections from published studies of Himalayan wildlife, and a summary of recorded density data.

2.4.7 Census Operations in Tropical Evergreen Forest

Evergreen forest communities present especial problems for census operations. Virtually all terrestrial animals have very low densities (arboreal mammals can have high densities and biomass); visibility is often low, and in very thick 'secondary' undergrowth both visibility and movement can be close to nil. The forest environment can be very hostile (cane, leeches, mosquitoes, stinging nettles, heat and humidity, steep topography).

Animals may be specialists of poorly known habits (e.g. serow, takin, mouse deer, barking deer, binturong, linsang, Malabar civet, clouded leopard and other carnivores) necessitating effort into gaining basic knowledge of the species before the proper development of census methodologies.

What do we need to know ?

Nearly always we need to know much more about patterns of distribution. Even for large visible species such as takin we know little about broad distribution.

There are several species considered to be rare and endangered, e.g. Malabar Civet, and yet there is no information as to where in the Western Ghats the species can still be found.

For larger species, elephant, gaur, sambar etc., there is a need to know rough patterns of density, especially with regard to differential use of evergreen forest and more open adjacent deciduous forests.

There is still a need to know methodologies. How can one census tigers in the several hundred square kilometres of closed evergreen forest in Periyar N.P. in Kerala?

Suggested Census Operation

1) Comments on general reconnaissance survey in section 2.4.5 are relevant. Map presence and absence at a coarse scale, refine this as more information becomes available. Use information from local people. Employ knowledgeable locals (tribals) to help you question other people and check such information in the field.

2) Check key sites (water, salt licks, valley bottoms, fig trees or other preferred fruit localities). Use a machan or camera traps. Consider tape recorder play backs of calls. Look for spoor, dung etc. to show distribution.

3) Line transects can work in evergreen forest. Low densities can however make formal transects either ineffective or very expensive in that many are needed. Nocturnal, or shy hiding species cannot be assessed in this way.

4) There is still a need for experimentation, trial and error with census operations *and* the publication of results and methods. For tigers in Periyar there is a need to develop greater mobility and field work capability *before* better census can be attempted. Temporary camps need to be opened and a network of patrol trails established. Then cleaning some parts of trails from litter and placing pugmark impression pads may help.

2.4.8 Census Operations for Crocodilians

India has considerable experience in both the management and ecological investigation of crocodile populations of the three indigenous species:

Ganges gharial
Mugger or Marsh crocodile
Saltwater crocodile

Whilst many investigations have commented on population abundance, there has been no review of pertinent methodology. This section provides an introduction to suitable methods of census.

Direct and Indirect counts

Crocodylians being amphibious in nature can be counted directly both on land and water. Crocodiles basking on land during day time are easier to count and their size can be estimated. At night crocodiles floating on water or resting on land can be counted by using a hand held spot light and catching the reflected 'ruby red' glow from their eyes. Only a proportion of crocodiles will be visible at any one time. Others will be submerged. This proportion dependent on many factors such as ambient temperature and disturbance is highly variable.

Presence, absence and relative abundance of crocodiles in a given area can also be assessed from indirect evidences such as footprints and faecal droppings on the shoreline. An estimation of number of breeding females can be made by counting the number of nests laid each year.

In some cases it may be possible to attract nesting and nest guarding females to emerge from water by playing recorded 'grunting' calls of newly emerging hatchlings. This technique, however, is risky as nest guarding females may consider this as an intrusion in their territory, and attack.

Factors affecting count

Air temperature, day length and availability of sunlight for basking greatly influence the amount of time crocodiles can bask on the shoreline. Winter months, therefore, are a good time to count crocodiles during the day. During summer months, crocodiles avoid the high temperature of sunlight and spend much of their time submerged. During night, however, they surface or rest on land. Night spotlight counts during summer, therefore, are ideal. An additional advantage of a summer count is the low waterspread, restricting crocodiles into smaller areas. Low water depth during summer, however, makes it difficult for navigation by boat.

In coastal waterbodies influenced by tidal fluctuations, conditions at low tide are easier for the viewer to spot basking crocodiles. At high tide, the shoreline vegetation screens from viewers crocodiles floating or basking. The same problem is faced during night spotlight counts. Counts are usually restricted to the period of tide when 50 cm or more of exposed banks are visible from the base of vegetation lining the river.

These methods can only be undertaken in accessible habitats with a distinct water-land interface.

Census Operations

Planning a crocodile census operation begins with preparing maps of the survey area from topographic survey

sheets. An unit length of 10 km or multiples is advisable (Fig.1). Depending on the season of survey and the amount of time crocodiles bask during the day, the unit length can vary; except in winter nights when crocodiles prefer to remain submerged in water to avoid low surface water temperature.

Daytime and night spotlight counts can be conducted from a flat bottom (stable) boat, moving downstream. A crew of three members is ideal. One to spot crocodiles, one to navigate the boat and the third to record data.

The locations of each crocodile spotted are determined and plotted on the map. When possible, each crocodile is approached closely to estimate its size. With experience it becomes easier to estimate the size from a distance. A simple practice is to estimate the size of fallen log or debris on the bank and cross check its actual size to correct the pattern of size estimation error of each crew member.

With practice, the size of a crocodile can also be estimated at night from the distance between two reflected eyes.

On the basis of these observations crocodiles sighted and counted are assigned to general size/age classes. Size estimates are more of a guide to the population size structure than a precise measure of structure.

e.g.

- H - Hatchlings (< 50 cm)
- Y - Yearlings/Juveniles (> 50 < 120 cm)
- S.A - Sub Adults (> 120 < 180 cm)
- A - Adults (> 180 cm)
- E.O. - Eyes only

Individuals that can not be approached close enough to enable a size estimation to be made are recorded as *eyes only* (EO) crocodiles !

Other parameters such as time and location of sighting, activity of the sighted animal, weather conditions, moon stage, habitat condition, water level etc. are recorded along with crocodile data. These data will help in analysing population density fluctuations in different areas and suggest reasons for change in densities from time to time.

Recording census data

A separate data sheet for each day/night survey or a total river length unit should be kept. By compiling data from all these sheets, the population density for each river system can be calculated. Usually data are expressed as numbers per km of river. A suggested proforma sheet for this is as follows:

Table I Crocodile Census Data Sheet

River _____ Day/Night count Date: _____
 River unit (other) length to cover. _____

Size Class	Number seen	Location				Feeding
		OL	IVIM	SWOE	MS	
Hatchling < 60 cm						
Yearlings >60 < 120 cm.						
S.Adults > 120 < 180 cm.						
Adults > 180 cm.						
EO (Eyes only)						
Total						

OL - On Land; IVIM - In vegetation in water;
 SWOE - Shallow water on edge; MS - Mid stream.

Name of Observer: _____

Data Analysis

After the census of all such units of a river system or lake system are completed, the data can be compiled into a master sheet.

Table II - The data below are the actual census data of saltwater crocodile in Blyth-cadel river in Australia (Source: Messel et al. 1984).

System		Size class numbers					Total km surveyed	Density* per km	
		H	Y	SA	A	EO			
Blyth-Cadel river									
Feb 1987	82	167	67	6	26	348	92.0	2.9	
Feb 1988	105	177	68	4	32	386	90.5	3.1	
Feb 1989	155	129	82	6	17	389	90.5	2.6	
Feb 1990	72	137	68	7	31	315	89.9	2.7	

* The hatchling size classes are excluded from calculation of density.

Reference

Messel H, Vorlicek, G.C. Green, W.J. and Onley, I.C.1984. Survey of tidal river systems in Northern Territory of Australia and their crocodile populations. Monograph No.18. Population dynamics of *Crocodylus porosus* and status, management and recovery. Update 1979-1983. Paragon Press: Sydney.

The density of crocodiles in a river or lake system is calculated by dividing the total number of non-hatchling crocodiles seen by the number of mid stream kilometres of river and tributaries surveyed.

Although a mean day or night count density can be calculated for a river system surveyed each year, it is biased by mix of high and low density locations in each river system surveyed. The result of a count can vary greatly with physical conditions (water level, weather, moon stage etc.) and disturbance factors operating in the habitat as well as the experience of the counting personnel.

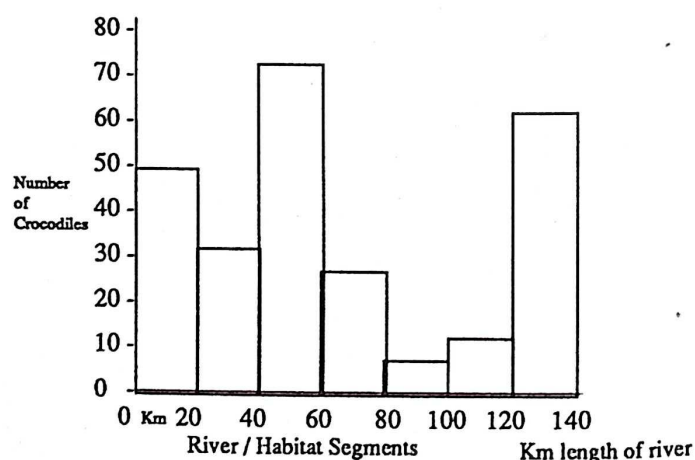
Since there are many interacting independent variables (as explained above), whose independent contribution to the density of crocodiles in any given area is not known, a linear regression analysis is unlikely to be an estimator of density.

Therefore, the usefulness of the spotting count is not in determination of an exact population figure but it is a method that can yield an index of the number of crocodiles present at any given time. Sustained regular surveys and census can thus provide information on both the status and the trend of the population.

Note that the method outlined here does not allow the determination of the proportion of animals visible at any one time. There may be half or more of the population under water during the operation, and this proportion is variable. However, repeated censuses and data on environmental variables can allow statistical computation of such a proportion, and so estimate a total population.

Presenting the data

Relative density of crocodiles in different parts of the habitat can be represented from data gathered in a graphical form.



Such graphical presentations can help management to emphasize protection/management efforts in specific areas depending on crocodile densities rather than diluting effort all over the habitat, and can also show features of habitat importance, limiting features etc.

Graphical presentation of densities for each year gives information not only on the population trend, but also on the changes in distribution of crocodiles in different areas.

Graphical presentation of number of crocodiles sighted during each successive census in a given area will also indicate the survivorship of each size class as also recruitment of sub-adult size classes into adult size class.

Notes on Censusing Indian Crocodilians

Three species of crocodilians occur in India. The long-snouted gharial (*Gavialis gangeticus*) is a resident of Ganges, Brahmaputra, Indus and Mahanadi river systems. It does not occur in other river systems of the Indian sub-continent.

Gharial is by far the most gregarious in nature. At any time of the year one may find congregations of all size-classes on a preferred mid river sand bar. This can make it difficult to classify them into different size categories. It is also difficult to approach them very close, being shy they slide into water at the slightest provocation.

The Estuarine or saltwater crocodile (*Crocodylus porosus*) is restricted to the mangrove swamps of the east-coast of India and the bay Islands of Andaman and Nicobar. The main rivers and creeks within mangrove areas— all support *C. porosus*.

The freshwater Indian mugger crocodile *Crocodylus palustris* is by far the most widely distributed in the Indian sub-continent and could be found in many freshwater habitats ranging from small village ponds to fast flowing deep rivers. However, wherever mugger crocodiles share the habitat with Gharial, their numbers are very low.

The mugger crocodile is also gregarious but large congregations are rare to find in the wild. During the winter months, the adult size classes are mostly solitary. Muggers do not like very deep waters nor do they tolerate big waves, hence one may always find them closer to the shore rather than on mid stream in a big lake or river. Mugger prefer to bask on rocky outcrops or islands, rather than on mid river sand bars.

Summer nights are the ideal time for census of mugger crocodiles.

2.4.9 Census Operations for Primates

There is a considerable literature in India on studying the urban and agricultural populations of macaques and langurs (see for example references to Southwick and Siddiqui, and Seth and Seth).

However, this section comments on techniques suitable

for fully wild populations in natural forest situations. Two publications are of importance for detailed study of primate abundance, these are: Brockelman & Ali's "Methods of Surveying and Sampling Forest Primate Populations"; and National Science Foundation's booklet on "Techniques for the Study of Primate Population Ecology". Both are listed in the bibliography. Both should be consulted by persons wishing to census primates in evergreen forest situations.

Brockelman and Ali stress the need to determine the objective of the abundance survey as this will affect broad methods to be used

e.g.

For conservation planning (i.e. where should we protect Phayre's leaf monkey?)	Use a relative abundance mapping grid over whole distribution area.
For protected area monitoring (i.e. how many animals in this protected area?)	Use block counts or transect lines. Determine number of groups per area and later correct for mean group size.
For ecological study of a population	Intensive transect lines and recognition of groups.

Primates present three especial problems for the generalised wildlife census, in which all species (terrestrial and arboreal) are to be censused together.

1) Primates are highly diurnal (apart from lorises). Transect counts before 8 am or even later in winter may not be effective as groups will not be active and will be restricted to sleeping trees. For many ungulates transect timings may be most effective from first light to 8 am!

2) Group sizes are large. Common langur groups may often exceed 50 animals and counting such groups may require a long time period and so affect overall transect efficiency. Infants may be held by the mother and easily missed. Binoculars are essential. Better to count groups during the actual census operation. Later more detailed enumeration of a sample of groups will allow the correction of group density or group numbers to animal density or animal numbers.

e.g.

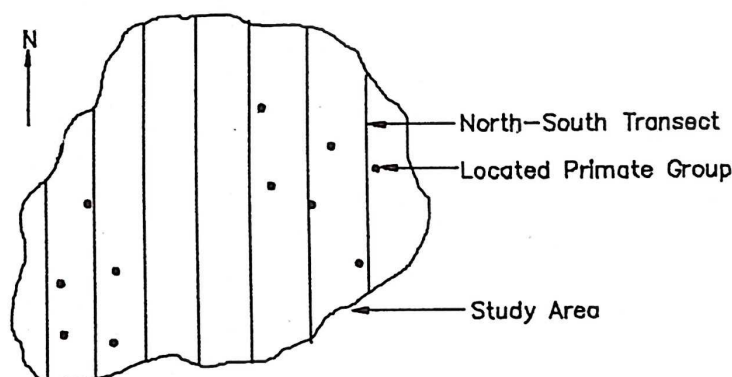
$$\begin{array}{rcl} 20 \text{ groups} & \times & 32.5 \text{ animals} \\ \text{(no. of groups)} & \text{(mean group size)} & \\ \hline & = & 650 \\ & & \text{(no. of animals)} \end{array}$$

(based on counting a sample of say 10 groups)

3) In tall evergreen forest the census search will have to be three dimensional. Observers should scan the canopy for movement as well as the ground. Often primates in the canopy are heard before they are seen; branches moving, twigs snapping. Some observers stop and listen for 20 seconds or more every 50m. If primate populations are greatly disturbed, then animals may "freeze" on hearing humans approach and detection will be very difficult.

4) For generalised survey use can be made of the loud territorial display calls, typical of langurs and leaf monkeys in the early morning. Such calls can give clues to the presence of the species, and allow them to be followed up.

5) Detailed studies should involve the use of a systematic grid of transects; e.g.



Primate sightings should be mapped as to position along such transects. Analysis of map plots can help you to identify groups, group home range sizes and so calculate density. If mean home range size is 2 per sq km, and home ranges do not overlap, then there will be 0.5 groups per sq km. If average groups size is 20 animals, then there will be a density of 10 animals per sq km.

2.4.10. Census Operations for Birds

Birds rarely come into the "accounts" of wildlife protected areas in India. Managers seldom count bird species, except those of immediate importance such as Siberian cranes or bustards. Many protected areas do not even have a check-list of bird species. Hopefully, this situation will be rectified as the importance of birds comes to be recognised, not only as part of the biodiversity of an area, but also as useful indicators for habitat status and efficacy of management measures.

This lengthy section introduces several possible techniques for counting birds. These are:

- Total Counting - useful mainly for waterfowl;
- Sample Counting - covering four methods:
 - mist-nets
 - foot transects
 - point samples
 - territory mapping.

The interested reader is advised to consult the detailed references listed in Section 4 of this manual and to seek specialist advice before undertaking detailed census work.

Total Counts: Mainly Waterfowl

It is not possible to attempt total counts of birds, except in case of larger more visible species restricted to specific

limited areas, such as waterfowl in wetlands. Such total counts of wetland birds can be conducted by walking or boating through or around the area, or observing from a vantage point such as a tower. Such counts too have not been part of the wildlife manager's routine work even in large wetlands. Three years ago, a notable effort was initiated by the Bombay Natural History Society in India, implementing the annual Asian Waterfowl Count; this has the objective of assessing population figures and trends of most waterfowl species in as many wetlands as possible. This seeks to involve hundreds of individual birdwatchers and agencies in collecting and collating census information. This may seem similar to the annual tiger census in India! All possible wetlands are visited by the census operators (volunteers) during a specific period in January, and all individuals of every species are sought to be recorded. Results of the first three annual counts (1987 - 1989) are summarised in the *Wetlands and Waterfowl Newsletter*, published by the Bombay Natural History Society. Wildlife officials in charge of wetlands can usefully become part of these counts, thus further strengthening the network, as also increasing the data. Further information on these counts - prescribed methods, data collection formats, timing, etc. can be obtained through Shri S. A. Hussain of the Bombay Natural History Society, coordinator of these counts, and editor of the newsletter.

Total numbers become important in conservation cases of extreme rarity, for species like the Siberian or Black-necked cranes, which may be on the verge of extinction, or occur in very low numbers. Total counts may be possible for large, conspicuous species such as bustards and floricans, and maybe some pheasants, using techniques similar to those described for mammals. But for the bulk of the terrestrial species, this is not feasible, nor is it necessary.

Sample Counts:

The utility of bird counts for a manager would lie mostly as indicators - for monitoring habitat status, assessing the effects of management inputs or as part of an environmental impact assessment of "development" projects.

For these purposes, the parameters of importance are:

- a) The number of species (species richness); note, this changes seasonally, with summer and winter migrants.
- b) The relative abundance of species in a community. (e.g. species A is more common than species B). It is not necessary to obtain the absolute abundance of every species.
- c) The number of a particular "target" species; this too need not be absolute, since target species counts are most useful for comparative purposes (e.g. species A is more common in habitat (or area) X, than in habitat Y; species A was more common in 1988 than 1990, or before a fire than after).

These parameters can be most easily measured through sample counts.

The basic concept of a sample count for birds is the same as that for mammals - counting in a representative area of a particular habitat. Such sample counts can be conducted in various ways - by capturing birds, counting singing males, sightings along foot transects or "point counts" from fixed locations. The basic steps, such as sample design to ensure adequate, proportionate representation of different habitat types, are the same for all purposes. Sample counts for birds requires a reasonably good acquaintance with the bird species of the area. It is essential that the person conducting the count be able to correctly identify most species encountered, or at least those target species. Ideally, the census operator should also be familiar with the songs and calls of target species. This is because most bird detections (and some identifications) are likely to be based on calls. In practice this would require spending time in the area before the census, merely becoming familiar with the birds, learning their calls and songs. This also helps in getting a feel of how they are distributed among the vertical strata of the habitat. One should know where to look for a given species - e.g. in the top canopy, on the ground, or among fruiting lianas.

1. Mistnet Sampling:

Thin, practically invisible nylon nets, called "mist-nets" are routinely used for capturing birds in forests. This technique (illustrated in the Wildlife Techniques Manual Eds., J.B. Sale and Klaus Berkmueller, WII) is particularly useful for birds of the understory - up to about 3 m above ground is the normal range. Captured birds may be ringed, or colour-banded, by putting plastic colour-coded rings around their legs. This is useful in the capture-mark-recapture method (see Section 2) where the ratio of marked to unmarked birds in subsequent counts can yield estimates of the population size. Alternatively, mistnet capture can provide simple indices of abundance, such as capture rate which is the number of birds caught/mistnet/hour.

Mistnetting is, however, of limited utility since it requires skill and experience, both in using the nets as well as in the handling and care of captured birds. It is also expensive in terms of effort, since only a limited number of species, of a particular vegetation stratum are sampled. It may be most useful in identifying and counting cryptic or "skulking" species, such as wren-babblers, chats or ground warblers.

2. Foot Transects:

Counts along transect lines, essentially as described for mammals, are useful for estimating relative abundances, as well as for estimating densities.

Relative abundance: The actual number of birds encountered (seen or heard) on a transect can act as a simple

index of abundance (numbers per km walked) for comparative purposes, e.g. monitoring bird populations from year to year in a given area, or comparing before and after some management measure. Care must, however, be taken to ensure that the visibility in the habitat is similar during all the counts being compared. A decrease in visibility may lead to fewer birds being encountered, even though the actual number may be the same. Since visibility often changes seasonally as a function of the amount of foliage, counting in the same season is an effective way of controlling for visibility. The conspicuousness of a bird also depends on its behaviour; birds, especially males, are highly visible during the breeding season when they are singing and advertising their territories. The best season for counts is thus the breeding season, when birds are most conspicuous.

Transects for relative abundance may be along roads or tracks through a habitat. The important criterion for comparison is to have similar conditions during each count, i.e. ensure repeatability. Take care that roadside edges are representative of the habitat to be sampled. Road going through dense forest often have edges of open sun-flower rich pioneer shrubbery, a very different habitat than dark forest interiors.

Density: The procedures for estimating densities from transect counts are similar to those used for mammals, (See Section 2.3.3), and the detailed references of Section 4).

Transect length should be such as to ensure adequate coverage within a specific time period. In practice, walking a bird transect of 1 km length requires about two hours, on reasonably level terrain in a forest habitat.

3. Point Count:

A variation of the transect count is the "point count". Here the observer stands at a fixed point for a specific period and counts all birds, either within a specified circle (of say radius 15 m), or as far as birds can be seen ("open" radius). This is actually like a transect count of length zero. Analysis is similar to that of transect counts, except that perpendicular distance is replaced by radius, and area becomes πr^2 instead of $L \times W$.

Point counts are particularly useful in areas of difficult terrain such as hills or swamps, where one cannot easily lay a straight, continuous transect.

4. Territory Mapping:

This is a standard method of counting birds in most ornithological studies, and widely regarded as the most reliable. The technique is based on locating singing males in an area on a map. This is done repeatedly (3 - 4 times) within a limited period (maybe a week, or the breeding season). A composite map is then prepared by overlaying the locations of each separate count. One can then find clusters of locations indicating territories of individual

males. The number of such clusters is thus the number of territorial males in the area, and assuming all of these are monogamous, one can then estimate the breeding population.

An obvious limitation of this technique is its being restricted only to the breeding season. It is not applicable to winter populations of migrants, a major component of the avifauna for most of peninsular India. Further, non-breeding members are left out. The technique also requires skill in identifying territories correctly from clusters (correct mapping) or it can lead to interpretational errors. This would require a degree of familiarity with the general ecology of the species, which would require extra effort. Hence this is of more limited use for a manager, than the generalised transect or point counts.

General Precautions:

1. All observers should be adequately trained in the methodology of bird census and should reach a comparable level of competence. This is particularly important in order to avoid observer bias in comparisons.
2. Counts should be conducted during the period of maximum activity. This is usually the hours just preceding and after sunrise. Counts should also be limited to this specific period, and not spread over the whole day.
3. Counts should be conducted during periods of clear weather, since clouds and rain can depress bird activity.
4. In comparative censuses, each count must be conducted at a similar time of day and under similar weather conditions.
5. Care must be taken to ensure that visibility in habitats being compared (or the same habitat at different times) is similar. Where this is not possible, existing conditions during the count should be adequately described. This will help in correct interpretation of census results.
6. Transect counts for birds *must be conducted separately*, and *not combined* with mammal transects. Bird counts require skills different from mammal counts: one has to walk very slowly and scan the habitat horizontally as well as vertically; one also has to listen carefully for calls and songs.

Finally, one might state that bird census is a more specialised aspect of general wildlife censusing, requiring more specific effort than large mammal census. It is most useful for specific purposes of management, such as assessing the usefulness or otherwise of management actions (e.g. impact of fire or selective logging), or for managing particular endangered or threatened bird species. As such, it can form a useful tool of the manager's repertory. But it is not necessary to undertake large-scale bird census in a routine fashion, as is done for large mammals.

2.4.11 Census Operations for Livestock

Traditionally, wildlife managers have not included livestock (cows, buffalo, sheep, goats, camels, horses) in their routine census operations. There may be several reasons for this: not considered important, most cattle are illegal and so this enumeration would be an admission of management inefficiency; different techniques may be needed etc.

Livestock are extremely important components of the ecology of most protected areas and *should be censused* accurately, frequently, and with regard to time and space. Livestock compete directly with wild herbivores for scarce fodder; they form a prey base for carnivores, they are a management problem, but also a major socio-economic support to rural people in and around the protected area. They should not be ignored! Livestock densities in Indian forests can be very high, over 150 per sq km, and densities are still rising. Densities are supposedly well in excess of forest carrying capacity.

What do we need to know ?

Several facts are of interest to managers:

- Total number and types of livestock using the protected area.
- Seasonal change in livestock use (dry, wet)
- Spatial pattern of livestock use (core/buffer, habitats etc.)
- Ownership of livestock and distance away from protected area.

How can management get these facts ?

- Managers could rely on revenue department animal husbandry department, statistics but these may not be accurate in forested regions, and may not reflect use of protected areas.
- Managers could rely on numbers entering the protected area via manned chowkies, but many more may enter away from chowkies, or not be fully recorded at gates.
- A special effort should be made to collect information:

Villages within the protected area

- count in the village before release from night stockades.

Villages peripheral to the protected area

- i) count in the villages.
- ii) count as they enter forest/leave the forest

(local informants will explain how far from the protected area cattle are drawn)

Activities in the protected area

- include cattle in all census proformas.
- compartment inventory.

Protected areas with a veterinary office should utilise his services in carrying out this livestock survey.

Census Analysis and Interpretation

3.1 THE USE OF CENSUS DATA IN WILDLIFE MANAGEMENT

Introduction

Census data should not be thought of as an end in themselves, or something to be sent off to higher authority and then filed away. A great deal of interesting information can come from an analysis of the data. Ideas can be grouped under three headings, e.g.:

- Relationships between numbers and time.
- Relationships between numbers and space.
- Relationships between different species.

Number & Time

"Are populations increasing or decreasing?" is the single most important output of a census. This topic is treated in more detail in section 3.3, where the determination of population trends and rates of population increase are discussed.

Number & Space

The abundance of a particular species is controlled by a combination of factors related to past and present habitats e.g. food, water, cover, predation, disturbance etc.. Plotting census data on maps or grids allows an immediate visual appreciation of abundance information (see section 3.4 and box 12).

However, this data can be analysed more precisely to show cause and effect between environmental variables and abundance. Examples could be :

- a) Comparison of species densities in areas of high and low water abundance, or steepness of terrain, or core and buffer areas. [See example core and buffer zones densities in Melghat, Box 3, section 2.3.1 (iii)].

Give each compartment or grid square a ranking, e.g. 0 1 2 for no, some and much water, or flat, gentle &

steep for terrain.

Calculate the mean density for each group of compartments or squares, and see if they differ.

A data set for chital in Sariska showed the following pattern:

- | | |
|---------------------------|------------------------|
| - Flat to gentle slopes | 30 + animals per sq km |
| - Steep slopes | 2 animals per sq km |
| - Very steep rocky slopes | 0 animals per sq km |

b) The same can be done for management practices - give compartments or grid squares a subjective score (0,1,2,3 etc.) for intensity of fire, or grazing, or timber working, or village presence etc..

c) The same can be done for vegetation types. Give each compartment/grid square a single category, e.g. sal, miscellaneous, riverine, hillslope pine, plantation etc. and again look at mean density values within each vegetation type.

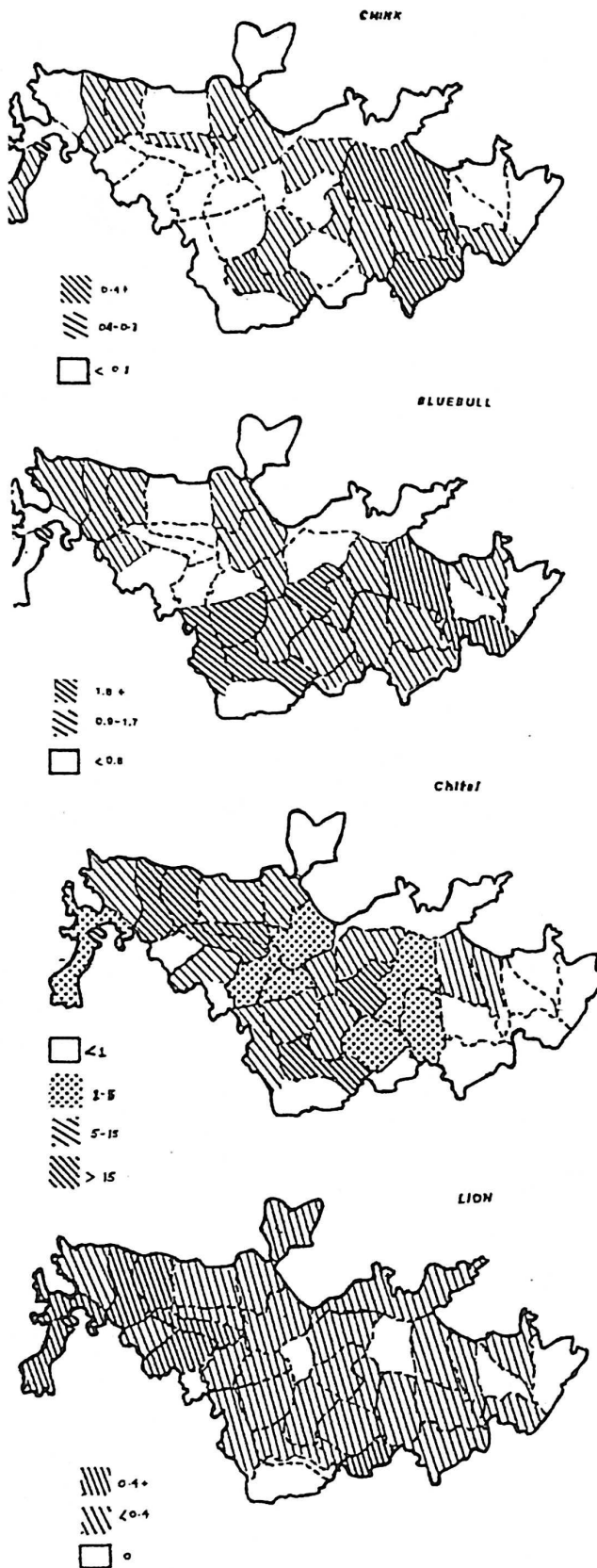
Note that for all these categorisations there will always be some problems - what if a compartment is only half burnt or if a square is half sal and half sissoo? Two solutions can be used, either create extra categories, e.g. Sal-Sissoo mixture or partially burnt; or make a decision that if more than 50 of one type is present then only that type is used, or if a block is more than 20% burnt, then it counts as a burnt block. Too many categories can create problems for later analysis!

Relationships between Species

A simple example is the relationship between prey and predator populations. The 1979 Gir Wildlife Sanctuary census data, for example, shows a significant relationship between lion population size and total prey base when analysed over all six ranges of the park ($r = 0.64$); however, lion population size shows no significant relationship with chital population size ($r = 0.21$) suggesting chital numbers are not the main determinant of lion abundance and distribution. Greater refinement could be obtained with inclusion of cattle figures into the prey base, stressing the need for wildlife managers to include livestock in their census!

Box 12

Example of a Graphical Output of Census Data



1. Chinkara 2. Bluebull 3. Chital 4. Lion
Density distribution maps for 4 species in Gir N P and W L S
(Data in density per sq km per block).

3.2 ASSESSING CENSUS RESULTS — HOW ACCURATE ARE THE DATA?

Introduction:

More and more census data from Indian wildlife areas are becoming available. Some censuses are based on carefully collected actual count data, others tend to be little more than the summation of estimates or guesses by junior field staff. It is important therefore to know how much reliability you can place on census results. Some ideas on how to assess reliability are discussed in this brief section.

Comparison of Results from Two Techniques:

At intervals it is useful to undertake the census operation using two different techniques at one time. The techniques should differ in concept, not just sample design. For example a census with random transects and one with systematic transects would not be different techniques. A block count and a king census count would be different. If the two results are similar, then results can be thought to be accurate - it is unlikely that both methods have the same built-in level of bias (but see below). What is similar? Within the range of confidence limits, or within 20% of each other if there are no confidence limits.

If results are different, then something is wrong, and one estimate will be non-reliable. Which one? - is a difficult question, checking assumptions inherent in each technique may suggest which is at fault, or repeat the census operations and see if differences persist.

Do Results from Several Years Follow a Logical Trend

If you have results for four consecutive years and they are similar to each other then they may be considered repeatable. If one more census is undertaken in the same conditions, then another similar result would be expected; a different result would suggest a real change in population size.

If the results show a general trend to increase or decrease (e.g. 701, 760, 755, 782, 806) then it is probable that the results do indicate a real trend in the population.

If the results follow no logical pattern and vary widely (e.g. 701, 894, 553, 829) then no reliance can be placed on the figures and no trend can be suggested. It is just feasible that species with high natality and mortality rates in a very variable environment could have population data with such annual change.

Remember that whilst these figures may be taken to show a trend, there is still no knowledge of how accurate they are! Instead of 701, 760 etc., there may be 1,402 and 1520.

Repeat a Census:

If a census operation is repeated in a short time interval and results are similar, the method can be thought of as repeatable (see above).

Assessing the Census Operation:

Two things can be considered here - how good and how appropriate is the technique for the particular situation, and how well has it been carried out.

i) Rethink the assumptions. If for example you have a waterhole census operation, present methods use an assumption that animals drink once per 24 hours. Is this realistic? Can one assume that chital and nilgai have identical water requirement? The answer must be no, and so less reliability can be placed on the results.

Or, in a rhino census from elephant back, it is assumed that all rhino will be in short grass or burnt areas and hence will be readily seen. Is this so? How big a proportion may be in unburnt areas, because that is their home range, because it is a hot day, or because a female has a very young calf etc? Note that some unknowns can be tested. For example a detailed survey of a small burnt/unburnt mosaic can be made, where unburnt areas are thoroughly searched and a correction factor applied to the total survey.

In a well protected forest area, the number of chital seen along permanent transect lines may decrease. Is this a real population decline or a function of reduced visibility in thicker cover following protection?

ii) Examine the operations. How good are the field staff doing the counting? (It is not possible to use 100 people and find them all equally keen and motivated!). Can staff levels be improved by using trained teams of selected people?

How adequate is the sampling design? This can often lead to major problems in overall results. For example if a road transect system is used and road side verges are attracting deer, than grossly exaggerated results may be obtained. A walked transect system which avoids steep terrain or only sparsely covers inaccessible areas may lead to biased results.

Final Caution:

There is no such thing as a perfect census technique. All have advantages and disadvantages compared to others. All are based on assumptions which sometimes may not be met. It is the task of the census organiser to select the best technique, check the assumptions, and try to ensure that as many as possible are either met, or can be compensated for by correction factors (See 3.4 below on presentation of results).

3.3 ASSESSING POPULATION INCREASE INFORMATION

Introduction:

Wildlife census operations are not an end in themselves. The results of a census, be it an index or an absolute number are only of value when used to interpret the past behaviour of a population, or predict future changes. One means of interpretation is determining rates of increase (which may be positive, or negative - indicating a decrease in numbers).

Note that one way of judging conservation success is by the presence of a stable ecosystem; a system where numbers of component parts are relatively constant. Population sizes may fluctuate, but within limits, giving what can be termed a steady state. Populations cannot go on increasing for ever, resources are finite. Most populations in Indian protected areas have shown increases since the major conservation efforts of the 1970s and 1980s. As the numbers rise and reach a new level of compatibility with the environment, we would expect to see a levelling off in population size. How can this be analysed?

Methods:

1) Analysis requires compatible sequential data. By compatible is meant collected in the same manner, or by techniques known to give similar results. For example, in 1980 there were 1200 chital from a vehicle road count, and in 1982 1500 chital from a series of foot transects. Is the difference real, or due to different techniques? If you wish to change census techniques, e.g. you did vehicle counts from 1978-1981 but wanted to do foot counts in later years, then do both in one year, at the same time, to get a correction factor.

2) Portray census data graphically, with the year on the bottom or "x" axis, and numbers on the vertical or "y" axis, see fig 1.

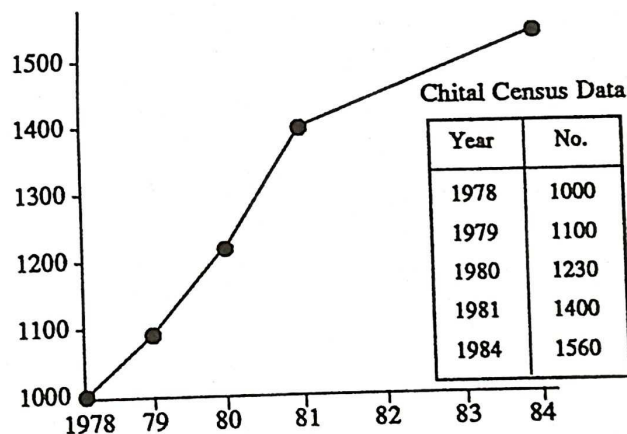


Fig 1 Arithmetic Plot of Census Data

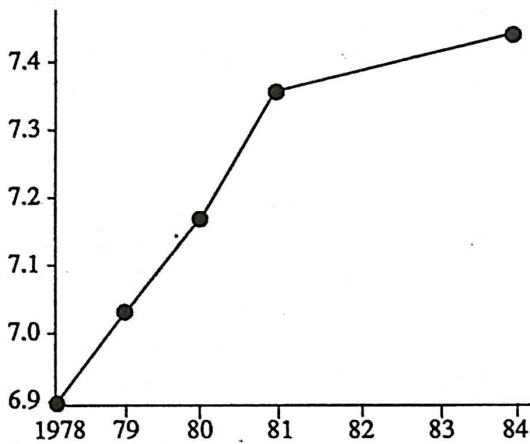


Fig 2 Log (natural) Plot of Data

Note the absence of some years data is not a major problem but less understanding of processes is possible. Plot the data as a logarithmic (natural or base e logs) graph, see fig. 2. In this case, straight lines indicate the population increases at the same rate each year.

3) Rate calculation. One simple method is to determine the finite rate of increase.

If: Year 1 = 1000; Year 2 = 1100

$$\frac{\text{No. in year 2}}{\text{No. in Year 1}} = \frac{1100}{1000} = 1.1 \text{ Proportional increase over the period}$$

Here a rate of 1.0 indicates no change e.g.	$\frac{1000}{1000} = 1.0$
a rate below 1.0 indicates a decrease e.g.	$\frac{800}{1000} = 0.8$
a rate above 1.0 indicates an increase e.g.	$\frac{1100}{1000} = 1.1$

The difference between the rate and 1.0 is the actual change. Each 0.1 corresponds to 10% in the time period: 1.1 is 10% increase; 0.8 is 20% decrease, 2.1 is a 110% increase etc..

4) For longer periods Year 1(1978) = 1000

Year 7(1984) = 1560

$$\frac{1560}{1000} = 1.56 \text{ in 7 years}$$

For the average annual rate divide 0.56 by 7 = 0.08. The population has increased by an average of 8% per year.

5) An easier statistic for population change is "r", the exponential rate of increase, but this requires the use of natural

logarithms or an electronic calculator with exponentials. The easiest way of calculation is

$$\text{Log}_e \text{ No. at } t_1 - \text{log}_e \text{ No. at } t_0$$

Where t is the number of years between times t_0 and t_1

For the previous example from 1978 to 1984, number at t_0 is 1000, and 1560 at t_1

$$rt = \log_e 1560 - \log_e 1000 (t=7)$$

$$rt = 7.35 - 6.91$$

$$rt = 0.44$$

$$r = 0.44 / t = 0.44 / 7$$

$$r = 0.063$$

How to use this statistic? If this rate continues until 1990 what will the population be? This is 6 more years.

$$rt = \log_e N_{t_1} - \log_e N_{t_0} \quad \text{Another way of expressin this is:}$$

$$0.063 \times 6 = \log_e t_1 - \log_e 1560$$

$$0.378 + 7.35 = \log_e t_1$$

$$N_t = N_0 e^{rt}$$

$$N_t = 1560 \times e^{0.063 \times 6}$$

$$N_t = 2271$$

$$7.728 = \log_e t_1 \text{ Using anti-logs } N_{t_1} = 2271$$

There will be 2771 animals in 1990.

6) A useful expression is the time taken for the population to double (or halve). Divide $\log_e 2$ by r. For the above example

$$\frac{\log_e 2}{0.063} = \frac{0.693}{0.063} = 11 \text{ yrs.} \quad \text{The population will double every eleven years.}$$

Use these formulae on humans as well! Surma village adjoining Dudhwa N.P. has 635 people and r is 0.034. In 10 years there will be 892 people.

3.4 PRESENTATION OF DATA

Introduction:

The objective of a census is to produce information of value to the wildlife manager or biologist. It is important therefore that this data is presented in the most useful way. When I am told of the number of animals in an area, I am immediately interested in two things. How precise is this estimate, i.e. what are the confidence limits to the estimate? How accurate is the census, i.e. what were the methods? Sufficient information should be given to allow the reader to evaluate both these very important conditions.

With a little care and preparation much more useful data can be given than just population size. Where the animals are distributed is also important to know.

This section is written to try and improve the manner in which census data are presented.

Census details:

Sufficient information should be given to allow the reader to repeat the census if he so wished. The reader may be the next manager who has to redo the same sort of census. List in adequate detail the following information

- : Specific objective of census operation
- : Key species for the census operation
- : Date of census and times
- : Total area which was considered
- : Methodologies used:

Give broad description of method

Give details of any stratification

Give sampling intensities, numbers and sizes of samples within each stratum.

Describe numbers and experience of staff undertaking census.

Give a map showing locality of strata and sampling units.

Detailed results:

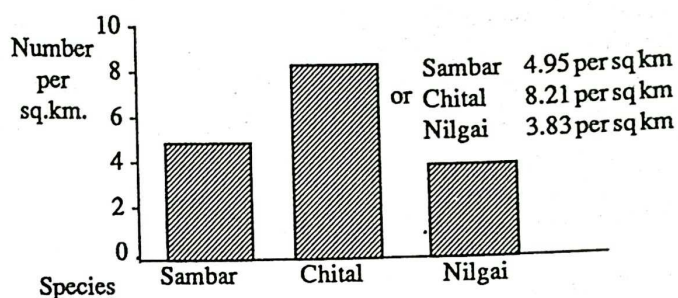
If separate strata are used then data should be presented for each stratum separately, with a later total. Results should either be given with estimates of variability, or with sufficient information for the interested reader to calculate his own estimates. Give always the number of sample units and the variance or standard deviation. This will allow readers to calculate standard errors, coefficients of variation, confidence limits and to use data in statistical "t" tests for comparisons with other areas or times.

Not all the data need be given in the main report. Some, such as numbers counted per individual sample unit could be put in an appendix. Biologists find density a more useful statistic than numbers alone. Be sure to include sample unit sizes and stratum areas so readers can calculate densities.

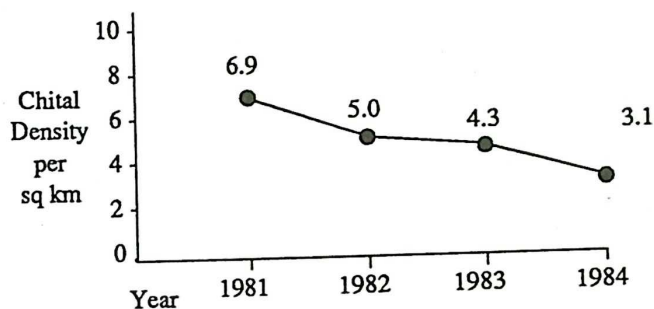
Tables or diagrams?

Data is nearly always best given in tables if other people are going to use the numbers for their own calculations. Diagrams are useful to help readers see relationships between variables.

For example: Which is more useful :



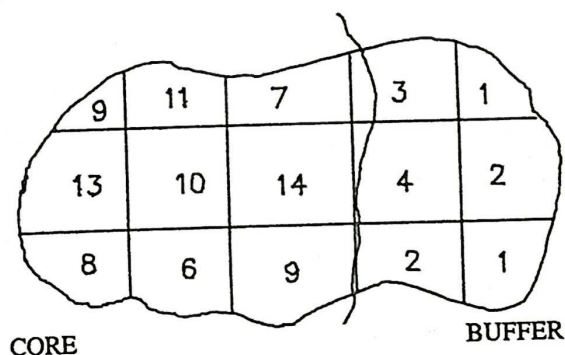
Use the table, it is a nuisance and inaccurate to have to read off numbers from a graph axis. But:



In this case use both! The graph gives an immediate and strong visual impression of continued decline. The figures allow the reader to calculate rates of decrease etc.

Relate census data to the environment:

This is partially achieved by using densities. But as protected areas usually have many environmental types, it is useful to show density for each type separately. This is often best done diagrammatically, e.g.



Total wildlife density by compartment in core and buffer zones. Data are numbers per sq km.

This diagram integrates numbers and area as density, and shows the spatial pattern of this density with respect to core and buffer zones. The text can add to this by giving overall means, e.g.

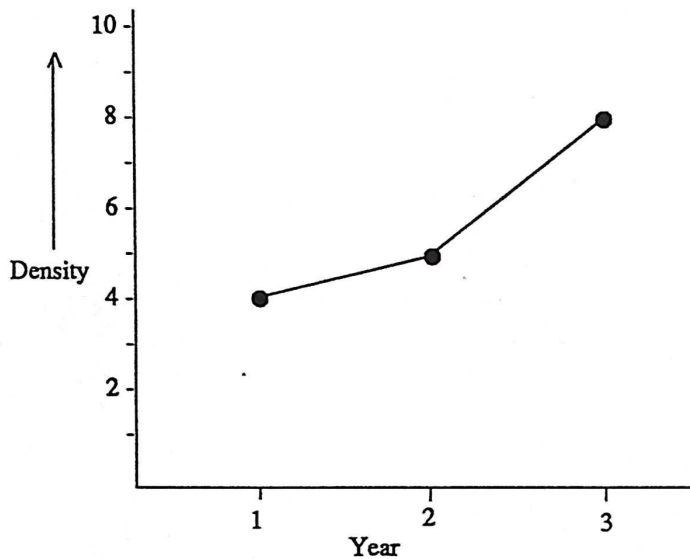
Mean density (unweighted) for core = 11.2 per sq km
Mean density (unweighted) for buffer = 2.4 per sq km

A real life example is given in Box 12. Data is taken from the 1979 Gir Census (dry season waterhole census) for 4

species, and plotted and mapped on a block basis. The difference between chital values (preferring denser forest) and chinkara/nilgai values (preferring the open East) is obvious. Note almost total absence of animals from edge blocks in the north & far north east.

Remember to use estimates of precision:

If you have census estimates for three years running, you can portray them graphically : e.g.



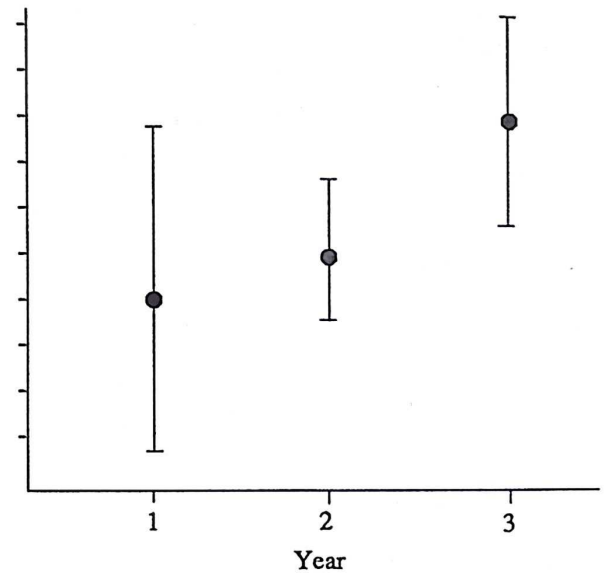
This suggests an increase, but using the confidence limits around the estimates of density shows there is actually NO significant increase.

(Note with large data sets, more detailed statistical tests around such serial data may be able to show significance).

Final caution:

Remember census totals are almost never absolutes. They are estimates of the real total. Such estimates may be good, i.e. close to the true value; or poor, i.e. not close to the true value. A single figure for a population estimate from a protected area is almost useless as a reader has no way to evaluate that estimate. Give the reader the methodology,

Chital Density
+/- 95%
Confidence Limits



give him estimated precision, and relate the number of animals to the area and the environment as ecological densities.

Literature on Census Methodology

Literature on Wildlife Census Techniques and Applications

In the 1950s the Indian Board for Wildlife recognised the need for accurate wildlife statistics and recommended the preparation of a guide to census techniques. A booklet "A Field Guide to Big Game Census in India", was prepared by the late Shri K.S. Dharmakumarsinhji in 1959. The book is now perhaps of historical interest, but it did lay great stress on the need for experimentation, trial and error, and the dissemination of ideas and results. The need is just as great today. Interestingly the book mentions the probable value of light aircraft, long before such techniques were routinely used in Africa.

The development of Project Tiger in India in the 1970s has led to a standardised technique for large carnivore census, and this manual incorporates and discusses these techniques in the text (Section 2.2.1). No such standardised procedure or set of procedures has been produced for other species. A methodology suggested for the monitoring of animals for Project Tiger Areas in 1977 has not proved practical to implement. States, protected areas, and individual managers have, over the years, developed their own favourite methodologies. Rarely however, have such techniques entered the literature, but two notable exceptions are:

- | | |
|-------------------------------|------------------------------------|
| a) The Palamau Track Census: | Cheetal 13(1)pp 15-26 of 1970 |
| (Discussed as section 2.1.6) | Cheetal 14(4) 14-19 of 1972 |
| | Cheetal 15(3) 43-47 of 1972 |
| b) The Uttar Pradesh Elephant | J.B.N.H.S. 66(2)pp 239-250 of 1969 |
| Census: (of V.B. Singh) | J.B.N.H.S. 75(1) 71-83 of 1978 |
| | Cheetal 27(4) 39-45 of 1986 |

The papers are of value in that they discuss methods AND the results. Both techniques do have problems however, and ideas on the broad methodologies should be consulted in this manual.

At the Kanha Workshop on Wildlife Techniques in 1981 there was some discussion on census methodology. Presented papers dealt largely with theoretical and statistical aspects of census. The Proceedings will be available from the Wildlife Institute of India in late 1991. The FAO/Wild-

life Institute of India "Manual on Wildlife Management Techniques" summarises a variety of the procedures described here.

Many wildlifers in India use the Wildlife Society of Americas's Wildlife Techniques Manual which has a large chapter on census methodology. The Third Edition, 1971, Ed. R.H. Giles, is available in India; printed by Natraj Booksellers. But the Fourth Edition, 1980, Ed. D.S. Schemnitz, is available in USA and can be ordered.

The major journals on wildlife in India carry papers dealing with census aspects from time to time. Examples are:

- Indian Forester
- Cheetal
- Journal of Bombay Natural History Society
- some publications of the Zoological Survey of India.

These papers tend to concentrate on results, methods are rarely discussed in detail. Some papers review census methodology from North America, usually in inadequate detail for proper understanding !

Recent text books dealing with census methodologies include:

- a) Seber, G.A.F. 1980 : Estimate of Animal Abundance and Related Parameters. London. Charles Griffin & Co.

This is *very mathematical* and much is concerned with trap/retrap techniques for small mammals. It is expensive and not recommended.

- b) Caughley, G. 1979 : Analysis of Vertebrate Populations, J.Wiley. One chapter on census, but a good discussion of problems of sampling. Also useful treatment of natality, mortality etc.

- c) Clarke, R. (Ed.) 1986 : The Handbook of Ecological Monitoring. GEMS/UNEP. Clarendon press, Oxford.

A good introduction to census and habitat studies, but much of the book is concerned with aerial techniques.

- d) Davis, D.E. 1982 : CRC Handbook of Census Methods for Terrestrial Vertebrates. CRC Press, Boca Raton, Florida, USA. Expensive!

The literature on line transects is voluminous. Those interested should try and consult:

Robinette *et al.* 1974. Field tests of strip census methods, *J.Wildl.Mgmt.* 38(1), 81-96.

Eberhardt, L.L. 1978. Transect methods for population studies. *J.Wildl.Mgmt.* 42, 1-31.

Burnham, Anderson and Laake, 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monograph* 72, 202 pages.

This again is very mathematical but is the key text on all aspects of transects. Anybody considering Fourier analysis must use this monograph.

The American journal, *Journal of Wildlife Management* is a good source reference to the recent literature on census for birds, waterfowl, small and larger mammals.

Those interested in the applications of aerial census should consult:

Norton-Griffiths, M. 1982. Counting Animals, African Wildlife Foundation, Nairobi; and:

ILCA, 1981. Low level aerial survey techniques. ILCA Monograph No.4. International Livestock Centre for Africa Addis - Ababa. Ethiopia.

Some detailed work on census in forest situations is in progress in West Africa (e.g. Barnes on elephant) but only preliminary results are available. Sale and Dawson are producing techniques using dung for elephant census in India. The Asian Elephant Specialist Group of IUCN should be consulted.

Census for Particular Species:

There is a large specialist literature on *primate* census (for forest and non-forest species). Two useful introductions are:

Brockelman W, and Ali, R. 1987. Methods of surveying and sampling forest primate populations. pp. 23-62. In: Marsh, C. and Mittermeir, R.A. (Eds). *Primate Conservation in Tropical Rain Forest*. New York. A.R. Liss. Publishers.
Techniques for the study of Primate Population Ecology, National Academy Press, Washington, D.C., USA.

A specific reference for non forest species in India is :
Southwick, C.H. and Siddiqui M.F. 1959-1965. Population Changes of Rhesus Monkeys in India. In: Else, J.G. and Lee P.C. (Eds.) *Primate Ecology and Conservation*. Cambridge University Press, Cambridge, U.K.
Bird census is covered in great detail by:

Ralph, C.J & Scott J. (Eds.) 1981. Estimating Numbers of Terrestrial Birds. *Studies in Avian Biology* No.6. Cooper Ornithological Society, USA.

Verner, J. 1986. Assessment of Counting Techniques. In: (Ed.) R.F. Johnston. *Current Advances in Ornithology*. Plenum Press, New York. Vol. 2

Taylor, K., Fuller R., and Lack, P.C. (Eds.) 1985. *Bird Census and Atlas Studies*. British Trust for Ornithology Tring, Herts, UK.

Crocodylians

I.U.C.N. 1971-1990. Proceedings of the Working meeting of the Crocodile Specialist Group of the IUCN/SSC. IUCN Publications New Series. Available from—The World Conservation Union. Avenue du Monte Blanc. CH-1196 Gland, Switzerland.

Singh, L.A.K. 1985. Gharial population trend in National Chambal Sanctuary with notes on radio-telemetry. Study Report (Mimeo). Crocodile Research Centre of Wildlife Institute of India, Dehra Dun. India.

FAO 1974. A preliminary survey of the prospects for crocodile farming (Based on the work of H.R. Bustard) FO:IND/71/033 FAO, Rome, pp.1-66.

Choudhury, B.C. & Chowdhury, S. 1986. Lessons from Crocodile reintroduction projects in India. *Indian Forester*, 112:881-890.

Messel, H. *et al.* 1974-1984. Survey of tidal river systems in Northern Territory of Australia and their crocodile populations. Published by Pergamon Press, Oxford, Sydney, New York, Toronto, Paris, Frankfurt.

Tiger Pugmark Census :

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Chaudhary, S.R. 1970. Let us count our tigers. *Cheetal* 14(2): 41-51.

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Appendices

5.1 CENSUS TECHNIQUES, SAMPLE TECHNIQUES AND STATISTICS

This appendix is an introduction to basic terminology and concepts in statistics and sampling.

A) Some Definitions and Concepts

Censusing is counting or measuring abundance of target items—wild animals in our case.

Sampling is the placing of counts in space and time.

Census Techniques try to obtain the best estimate of the number of animals in every sampling unit.

Sampling Techniques try to distribute the counting units so they are representative of the population.

CENSUS TECHNIQUES

A **Count** is a measure of one parameter of the sampled population — the abundance.

Measurement Error affects all counts:

A count possesses three principal properties which influence error

- Precision** - how repeatable are the results.
- Accuracy** - level of bias or wrongness.
- Efficiency** - ratio between precision and cost.

Precision Successive censuses of the same sample unit should give the same result if there has been no change in the system; the method thus has high **Repeatability**. **Variability** is the complement of **Repeatability**.

Variability of results can be measured by the **Variance**.

Precision affects **Sensitivity**, which is the power to detect small differences. If you want to pick up a change in density of 10% in one time period you will need a more sensitive survey, i.e. a survey with greater precision, than if just the capability to detect changes of 25% was acceptable.

Bias is departure from the true value, and can be random or directional, i.e. **Positive Bias** gives a higher than the true value and **Negative Bias** gives a lower value.

SAMPLE TECHNIQUES

Sample Technique possess three essential properties:

- Intensity** - Sample effort, or proportion sampled to the total.
- Representativeness** - the range of variation in the population is covered proportionately.
- Efficiency** - using prior knowledge of the pattern of variation to get greater precision with reduced cost.

Finally, the census technique uses an “**estimator**” to convert observed measurements in the field to estimates of the real population value. An estimator is a function of the sample data that describes a parameter of the population.

For example the King Census Estimator (for foot transects, see section 2.3.3.

uses $n/2Lr$ as the estimate of $\hat{D}$, or animal density. (where n = Number of animals, L = Transect length, and r = Mean radial sight distance).

Estimates should have three major properties:

- Convergence** When variance and bias reduce as sample size increases.
- Lack of Bias** Mathematical expectancy equals the population parameter.
- Efficiency** One estimate is more efficient than another when variance is smaller.

The relationship between these components of the process of estimating density from sample counts is shown in the diagram below.

Error : The properties of census techniques, sampling-techniques and estimators affect both:

- i) **Random Error** and hence range of confidence value of

the estimate
ii) **Systematic Error** (or bias) and hence the exactitude of the estimate

Random Errors can be decreased by:

Repetition of census.
Choice of efficient techniques & estimators.
Choice of convergent estimator
Increasing sample size.

Random Error is dependent on:

Precision } of census techniques
Efficiency }

Systematic Error is dependent on:

Accuracy of census technique.
Representativeness of sample technique.
Lack of bias in estimator.

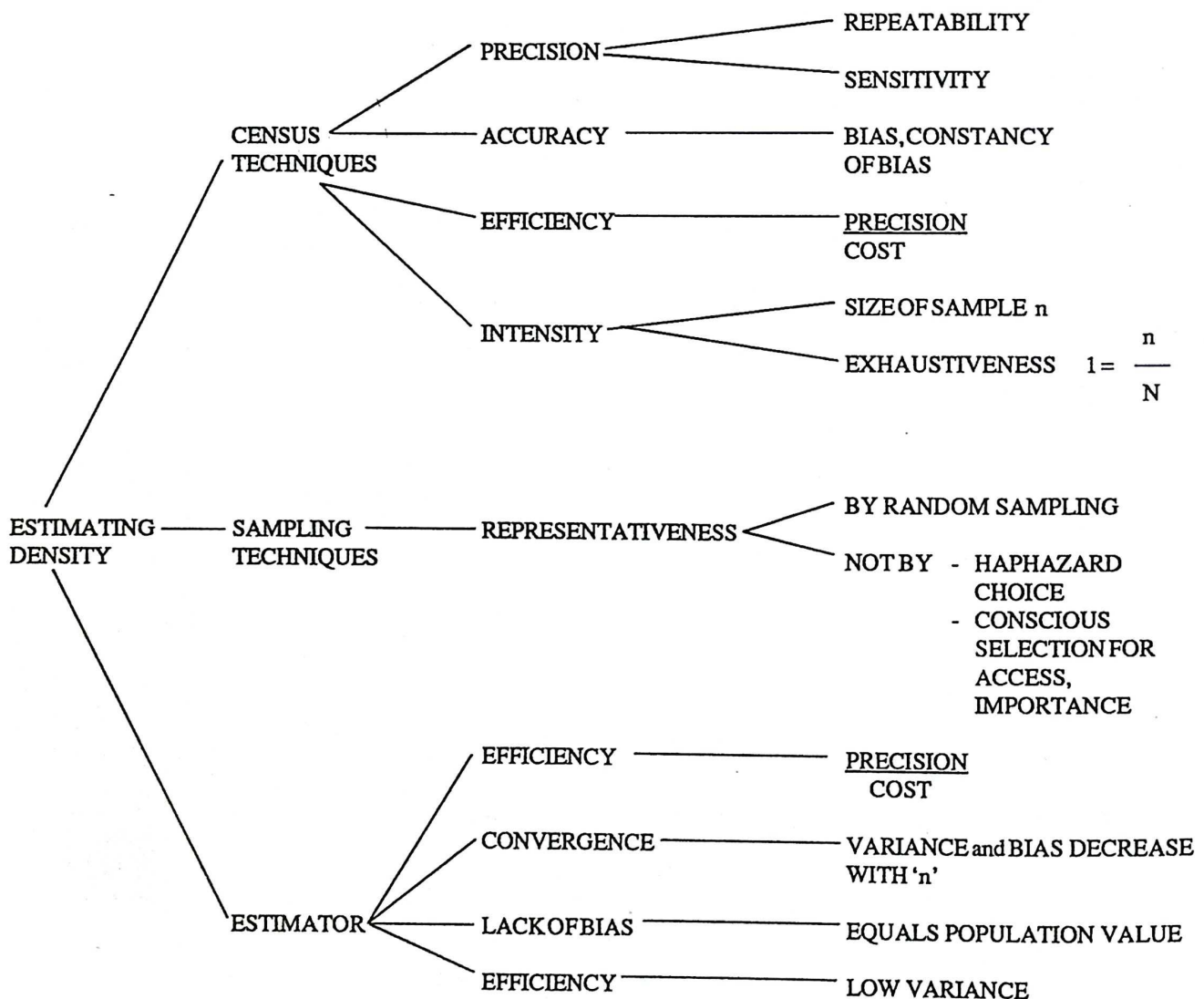
Intensity } of sampling techniques
Efficiency }

Systematic Error can be decreased by:

Calculation and correction factors.
Prior knowledge of population variation.
Larger sample size.

Convergence } of estimators
Efficiency }

Diagram to illustrate relationships between components of an estimate of density.



Types of Random Sampling Techniques

Six techniques are briefly described.

Simple Random Sampling (SRS)

Every unit of the statistical population has an equal chance of being selected. The method has the advantage of the use of many statistical tests.

Stratified Sampling

This is the subdivision of a heterogeneous population into several homogeneous subpopulations and then random sampling within each. This technique gives greater efficiency than SRS, but statistical tests are more complex.

Systematic Sampling

Random choice of first sample followed by a regular pattern of subsequent samples. This allows a more even coverage and permits mapping. The statistics may be more complex.

Unequal Probability Sampling

This is the selection of units with a probability proportional to their size.

Multi-Stage Sampling

This may be the choice of say 3 ranges out of 7 in the protected area and then within those 3 ranges a second stage sampling takes place as above.

Double Sampling

This could be the choice of 20 census units for extensive counting and then the subsequent choice of 5 of those initial units to be counted in more detail.

5.2 VARIATION AND STATISTICAL TESTS

Note: This section does not pretend to replace a statistics text book, nor to reduce the need for the serious census operator to discuss their sampling activities with a statistician. Reading this section may help a novice understand a text book or prepare for a meeting with a statistician.

About Samples

The purpose of a *sample* is to *estimate* the result that would have been obtained had every unit of the area been measured or counted. This leads to the assumption that the sample must be *representative* of the whole population.

We sample a *population* of items in order to estimate *statistical parameters* of *variable quantities*, e.g. density of animals in an area. We are interested in two sorts of parameters:

- i) The *average value* of the variable—the *arithmetic mean*.
- ii) The characterisation of variability among the values of the variate, *measure of dispersion*—the *variance*.

Sampling Areas and Sampling Units

The sampling area, often called the "sampling universe" is the area for which a population estimate is to be made. It is often identical with the protected area or a sub section of it. Such sub-sections can be defined as habitat types or land forms (grass-land, riverine forest, wooded valley, grassy plateau), but may also be management units (compartments, blocks, buffer zone). These subsections may be the strata used in stratified sampling.

Sampling units are the individual portions of the sampling area which may be counted. In theory all of the sample area could be counted, but in practice only a fraction of the potential units will actually be counted. These units should be chosen at random and are usually scattered throughout the sampling area.

Assumption

The basic assumption in sampling is that the samples should be representative of the entire sampling area. Obviously, selecting sample areas from only the core zone or along cut road-sides will not give a representative sample for the whole area.

Sampling

There is considerable variation in all attributes of natural populations. For example, the weights of chital males are not exactly the same; the ages of male sexual maturity vary from place to place. The density of chital from place to place will also vary. In a particular location density will also vary in time and in space. If we have a 10 sq km sanctuary with exactly 100 chital there will be an average density of 10 chital per sq km. This does not mean every sq km has 10 chital - some will have none, some may have 50! An area with no chital today may have 50 tomorrow, so notice that density distributions continuously vary in space and time. It is this variation which makes sampling a little complex to understand and implement.

In order to understand the basic principles of sample counts and some of the mathematics involved, consider the example in Box 13. The sampling area is a rectangular area of 2 km by 5 km, and it has a chital population of 100 animals and a sambar population of 20 animals. This sampling area is divided into 10 units, each of 1 sq km, the sample units. One or more strips may be selected and counted, and the total population estimated from this sample count.

However, taking one sample only would give plenty of opportunity for a large sampling error in the population estimate. If for chital it happens to be sampling unit 9, total population would be estimated as $10 \times 16 = 160$ chital, in case of sampling unit 1 it would be $10 \times 4 = 40$ chital. This error would be reduced dramatically by counting more than one

unit, and using the mean of all counts to estimate the total population size. Examples of this are worked out in Box 13. We can see that there is inherent variation in the population itself and there is also variation due to our level of sampling. A small sample will give more variable results than a large sample, no matter how the animals are distributed. In case of a non-random distribution you need a much larger sample to get a better estimate. From these examples several questions arise:

- Can I gain knowledge about the level of variation?
- How can this help me in making the estimated results more reliable?
- How many sampling units do I need to count so as to get an acceptable amount of possible error in my final estimation?

To answer these questions we will have to discuss some statistical methods and terminology.

Note : The sambar population is more evenly distributed and has a lower level of variance.

The Variance and Standard Deviation

Every population can be described by two things, the mean and a measure of variation around that mean. We estimate these by sampling, hence we have an estimated mean and estimated so-called variance. The variance is a measure of how far the individual counts are from the mean. Obviously they are much farther apart in the chital example. For the sample, the *Variance* is calculated as the cumulative sum of the mean minus the value for each count. Finally this sum is divided by the number of sampling units minus 1. Some sampling units are bigger and some are smaller than the mean, so to prevent negative values from cancelling out positive values, we use the squared values of the measurements for the variance. The square root of the variance is called the *Standard Deviation* of the distribution around the mean, and is often referred to as "s". This is the beginning of many statistical calculations. Box 13 gives an example of how to calculate the standard deviation, but many pocket calculators give this value directly.

The Standard Error

We now have to combine the variability in the population with the variability due to our sampling effort*. As we saw earlier, the population estimate varies greatly due to changes in sample intensity, i.e. the number of units counted.

Combining these two variabilities into one value of variability for our estimated mean gives the *Standard Error*. This is simply the standard deviation divided by the square-root of the sample size (n = number of samples counted) or $s/\sqrt{n}$. The standard error around a mean tells you how close the estimated mean comes to the real value in the population. Obviously the standard error will get smaller as your sample size

gets bigger. See Box 13 for examples of standard error calculations.

- * Note that the population has an inherent variance in how animals are distributed with respect to the mean. The chital example has a greater inherent variability than the sambar. But our sample size will also greatly affect our estimate of this variation.

Confidence Limits

The standard error gives a statistical assessment of the probable range of values for the real mean. How confident are we that it is correct? Remember we are taking samples; there is always a chance that our samples fall in mainly high or low values and so the estimate could still be much worse than expected. We get over this by setting ourselves "limits of confidence". In biology, the lowest level of confidence that is in wide use is the "95% confidence limit", which means that "I am confident that in 95 out of 100 occasions the true mean lies between so much....of the estimated mean". There is still a 5% chance left that the true mean lies outside the given range! A 99% confidence limit would therefore have a larger range, as we are confident it could be wrong only 1 in 100 times. The calculations of confidence limits uses three things:

- The standard error around the estimated mean.
- The sample size (as again we have more confidence in bigger samples).
- The level of confidence required, e.g. 95, 99, 99.9%.

Confidence limits are expressed as: Estimated Mean Value $\pm$ Confidence Limit. They are calculated as the Standard Error (SE) multiplied by a constant (Z), which is dependent on the sample size. For large samples (>30 units counted) the constants are:

95% Probability	99%	99.9%
Z = 1.96	Z = 2.58	Z = 3.29

For sample sizes smaller than 30, the sample size has much more influence. For these cases a different factor is needed, which is taken from "t" tables in statistical handbooks. The relevant t-values are given in Appendix 5.3. Select the one that comes closest to your sample size and use that as value for Z.

Why Do We Need Confidence Limits?

Confidence limits give a measure of precision (see box 14) to the sample estimate and are *essential* to the *interpretation* of census data. If a density of 10 chital per sq km is found in year 1 and 14 in year 2, is this then an increase, or is it merely due to sample variation? If the confidence limits around the respective means do not overlap, you have a given measure of certainty (95, 99%) that the estimated densities indicated a real difference.

Box 13

An Illustration of Sample Statistics

Ten equal sized (1 sq km) census blocks were randomly selected within a 50 km² protected area, chital and sambar were counted in each. Results are as follows:

Block	Chital	Sambar
1	4	2
2	12	1
3	16	2
4	8	3
5	0	3
6	10	1
7	5	1
8	9	2
9	17	2
10	19	3
Total	100	20

Map of blocks

1	2	3	4	5
6	7	8	9	10

The first stage is to calculate the mean number per block.

$$\begin{aligned} \text{Mean} &= 100/10 &= 20/10 \\ &= 10 \text{ per block} &= 2 \text{ per block} \end{aligned}$$

The second stage is to calculate the variance. This is easily done on a cheap statistical or scientific calculator, such as Casio, available in India. Put the calculator on to statistics mode, and enter the data separately, eg. 4, 12, 16 etc. for chital. On the key board press:

"n" sample size = 10

" $\bar{x}$ " mean value = 10.0

" σ_{n-1} " standard deviation = 6.11

Without a calculator, the work is tedious but straight forward.

$$\text{Variance} = \frac{\text{Sum of (each value-mean value)}^2}{n-1}$$

Use a table for easier working: Using the chital example:

Block	Value	Value—Mean	(Value—Mean) ²
1	4	-6	36
2	12	2	4
3	16	6	36
4	8	-2	4
5	0	-10	100
6	10	0	0
7	5	-5	25
8	9	-1	1
9	17	+7	49
10	19	+9	81
Total	100		336 (This is known as sum of squares)

Mean = 10.0

Sum of Squares / (n-1) = 336/9 = 37.33

Variance = 37.33

Standard Deviation = $\sqrt{\text{Variance}}$ = 6.11

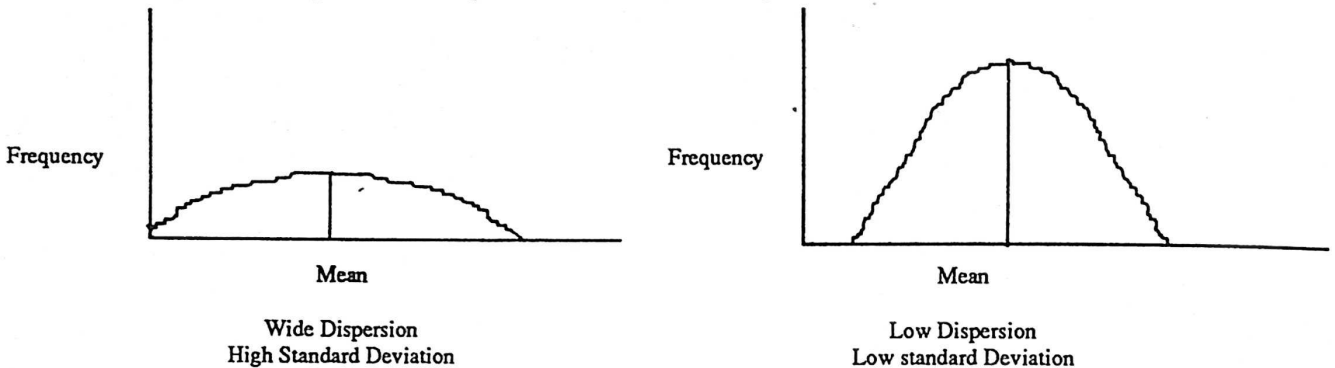
Which is the same result from the calculator.

(Box 13 Contd...)

(Box 13 Contd...)

We express the two results together as Mean plus or minus Standard Deviation 10.0 ± 6.11

This is a measure of how the sample values are dispersed around the mean value, eg,



Some statisticians express this as a "coefficient of variation - C", where

$$C\% = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100 = \frac{6.11}{10} \times 100 = 61.1\%$$

From the standard deviation we go to the *standard error of the mean*. This combines the variance due to the pattern of dispersal about the mean with the variance due to the level of sampling, eg.

$$\text{Standard Error} = \frac{\text{Standard Deviation}}{\sqrt{n}}$$

$$= \frac{6.11}{\sqrt{10}} = 1.932$$

This again is expressed with the mean, eg. Estimated Mean $\pm$ Standard Error = 10.0 ± 1.932 .

This is a measure of how far from the true value of the mean whole population our estimated value of the mean will be.

We use this value to make predictions from our sample. For example we can estimate the total number in the whole 50 sq km area.

$$\begin{array}{rclcl} \text{Total no. of Chital} & = & \text{Estimated Density} & \times & \text{Total Area} \\ 500 & = & 10 & \times & 50 \end{array}$$

But, our estimate of density could be wrong by a value of 1.932 either way. The density could be 11.932, when there would be 596.6 chital or 8.068, when there would be 403.4 chital.

But how confident are we that our sample was sufficient, by chance we could have chosen all high or all low values. Obviously, the bigger the sample, the greater the level of confidence. We can calculate confidence limits for our estimate.

Confidence limits are based on sample sizes, obviously we have more confidence in big samples.

Confidence limit = Standard Error $\times$ 't'

Where 't' is the value from the table of values of 't' for the sample size "n", for the desired level of confidence: typically 95%. 't' for a sample size of 10, is 2.23.

$$\text{So C.L.} = 1.932 \times 2.23$$

$$= \pm 4.295$$

Putting this together, Estimated Mean Density is

$$10.0 \pm 4.295 \text{ at } 95\% \text{ confidence interval.}$$

$$\text{or } 14.295 = \text{upper C.L.}$$

$$5.705 = \text{lower C.L.}$$

Note : for sambar the variability is much less. Coefficient of variation is 40.8%. Mean sambar density is

$$2.0 \pm 0.58 \text{ (confidence limits } 95\%)$$

i.e. 1.42 to 2.58 per sq km.

Box 14 Accuracy and Precision

An estimate of population size is characterised by two attributes: accuracy and precision.

Accuracy depends mostly on minimising human errors. For example: counting animals in tall grass means young will be missed, hence a negative bias (of unknown magnitude); a careless census team sights only 50 out of 100 animals present in a sampling unit, a negative bias of 50%.

Precision means minimising the confidence limits around the estimated mean population size. It is thus a measure of repeatability: if I repeat the census *in the same way* and I get a similar figure, then the results are precise.

Example: Real population size = 2300 animals.
Estimated population size = 1400 ± 70 animals.

This result has a bias of -40%, hence is *inaccurate*, but it has a *high precision*, with confidence limits of only 5%.

A high accuracy may be needed for estimating total population size. Accuracy can be improved through training of census staff, by choosing the best method for the particular purpose of the census, and by applying correction factors obtained through careful testing, to allow for known, constant levels of bias. A high precision is needed when monitoring the trend of a population, as I want to be sure to detect changes. Precision will improve by increasing the sample size, and consistently repeating the same technique, and by improving sample design, eg. stratification.

Bounded Counts or Jackknife Techniques

These techniques were developed in North America and have been described in the Wildlife Society's Manual of Wildlife Management Techniques (see references). They have been rarely used, all over the world, including India, although R. Chaudhary does discuss the method as it applies to waterhole counts (see Box 3 on page 17).

The method requires a number of repeated counts (the more the better, atleast 5) in a way in which theoretically there is the *probability* of counting all the animals in the area at one time. Note right at the start, there is a *need* for a total count and *repeated total counts*! The method works on the differences between the counts.

- (i) If in 5 "total" counts, the result was 100, 100, 100, 100, 100 the best estimate would be 100.
- (ii) If in 5 "total" counts, the result was 70, 80, 100, 60, 90 then as the count frequently missed many animals, there is a good chance that some animals were missed even when the highest value of 100 were counted, so the best estimate would be over 100.
- (iii) If in 5 "total" counts, the results was 98, 97, 100, 99, 98 then the best estimate would be just a little bit over 100.

The method uses the difference between the highest count $n_{\max}$ and second highest count $n_{\max-1}$ to calculate N, the estimated total number:

$$N = 2 n_{\max} - n_{\max-1}$$

In case (ii) above this would be:

$$N = 200 - 90 = 110$$

In case (iii) above this would be:

$$N = 200 - 99 = 101$$

Applying confidence limits shows up the major flaws in this technique as it applies in India. The lower confidence limit is always $n_{\max}$, i.e. 100. The upper confidence limit is (for a 95% level of confidence)

$$N_{\text{upper}} = n_{\max} + \frac{(1 - 0.05)(n_{\max} - n_{\max-1})}{0.05}$$

For case (ii) this is $100 + (19)(10) = 100 + 190 = 290$! Very high!

The fallacy is obvious, in accepting the $n_{\max}$ as the lower confidence limit, the method makes the assumption 'that no animal will be counted more than once'. This is obviously not true for waterhole counts and for total counts based on complete coverage of an area; there is a high probability of double counting.

The falsity of this assumption means the method has little application in Indian census.

5.3 SELECTED STATISTICAL TABLES

Table 1 : Student's "t". Values exceeded with probability p

df.	P=0.1	0.05	0.02	0.01	0.002	0.001
1	6.314	12.706	31.821	63.657	318.31	636.62
2	2.920	4.303	6.965	9.925	22.327	31.598
3	2.353	3.182	4.541	5.841	10.214	12.941
4	2.132	2.776	3.747	4.604	7.173	8.610
5	2.015	2.571	3.365	4.032	5.893	6.859
6	1.943	2.447	3.143	3.707	5.208	5.959
7	1.895	2.365	2.998	3.499	4.785	5.405
8	1.860	2.306	2.896	3.355	4.501	5.041
9	1.833	2.262	2.821	3.250	4.297	4.781
10	1.812	2.228	2.764	3.169	4.144	4.587
11	1.796	2.201	2.718	3.106	4.025	4.437
12	1.782	2.179	2.681	3.055	3.930	4.318
13	1.771	2.160	2.650	3.012	3.852	4.221
14	1.761	2.145	2.624	2.977	3.787	4.140
15	1.753	2.131	2.602	2.947	3.733	4.073
16	1.746	2.120	2.583	2.921	3.686	4.015
17	1.740	2.110	2.567	2.898	3.646	3.965
18	1.734	2.101	2.552	2.878	3.610	3.922
19	1.729	2.093	2.539	2.861	3.579	3.883
20	1.725	2.086	2.528	2.845	3.552	3.850
21	1.721	2.080	2.518	2.831	3.527	3.819
22	1.717	2.074	2.508	2.819	3.505	3.792
23	1.714	2.069	2.500	2.807	3.485	3.767
24	1.711	2.064	2.492	2.797	3.467	3.745
25	1.708	2.060	2.485	2.787	3.450	3.725
26	1.706	2.056	2.479	2.779	3.435	3.707
27	1.703	2.052	2.473	2.771	3.421	3.690
28	1.701	2.048	2.467	2.763	3.408	3.674
29	1.699	2.045	2.462	2.756	3.396	3.659
30	1.697	2.042	2.457	2.750	3.385	3.646
40	1.684	2.021	2.423	2.704	3.307	3.551
60	1.671	2.000	2.390	2.660	3.232	3.460
120	1.658	1.980	2.358	2.617	3.160	3.373
V	1.645	1.960	2.326	2.576	3.090	3.291

The last row of the table (V) gives values of d, the 'standardised normal deviate'.

df., the first column, is the degree of freedom, usually one less than the sample size "n-1".

Random Numbers

Random numbers are frequently used in planning sample census surveys, where a random or part random design is needed.

For example if you have a total of 84 census units and you need to select 21 units for actual counting and this selection should be random:

Go to Table 2 and take each pair of adjacent digits (or the first

pair of each five digit group). Any number over '84 would be ignored. Here you would take units

48, 46, 11, 49, 52, 72, 61, (ignore 97), 36, (ignore 89), 05, 59, 70, (ignore 86, etc.) 60, 08, 67, 04, 47, 39, 76, 53, 43, 81

Note numbers 52 and 05 were repeated and ignored the second time.

Table 2 : Random Numbers

A table of Random Numbers in 5 digit groups

48461	14952	72619	73689	52059
37086	60050	86192	67049	64739
76534	38149	49692	31366	52093
15422	20498	33901	10319	43397
70437	25861	38504	14752	23757
59660	67844	78815	23758	86814
59584	03370	42800	11393	71722
93804	09095	07856	55589	46020
04285	58554	16085	51555	27501
73883	33427	33343	45507	90069
68085	75447	30235	08190	42944
10980	35960	87461	79630	12952

5.4 CENSUS IN THE HIMALAYAS - SUMMARY OF PUBLISHED TECHNIQUES AND DENSITIES

A : Summaries of Published Methodologies for Estimating Wildlife Abundance in the Himalayas

The Himalayas offer one of the greatest challenges to the wildlifer in all aspects of ecology and management. Estimating abundance of relatively rare species in very difficult terrain is a difficult task. This appendix provides additional material for the wildlifer to plan, undertake, and evaluate census operations.

Copies of "methodology" sections are given from several published accounts of animal abundance in the Himalayas. Readers will note three things:

- a) Methods consist of much hard physical field work by a single team led by an interested and competent wildlifer. There are no easy or short cut methods!
- b) Methods are usually based on scanning and traversing suitable habitat in a series of block (valley/nallas) counts following a preliminary survey.
- c) Confidence in count results is increased by repetition of each block immediately, comparison with past work, or using a different method as well. This again means more hard work.

D. Mallon, 1983. Status of Ladakh Urial
Biol. Cons. 27:373-381

Methods and Study Area

I divided this study area into seven sections : (1) The valley of the Gya stream from the village of that name to Upshi; (2) the right bank of the Indus from Upshi to the Indus - Zaskar confluence; (3) the right bank of the Indus from Indus-Zaskar confluence to Khalsi; (4) the left bank of the Indus from Upshi to a point opposite Leh; (5) from this latter point to the Zaskar confluence, and the right bank of the Zaskar below the Markha river; (6) the left bank of the Indus from the Indus-Zaskar confluence to Khalsi and the left bank of the Zaskar river below its confluence with the Markha; (7) between Khalsi and the western slopes of the Fotu La (Fig.1).

I visited each section in turn, at first briefly, to assess its suitability for urial. There are several places, notably the right bank between Upshi and Leh, where steep, rocky ground providing little urial habitat occurs at low altitude. I then made intensive foot surveys with the objects of visiting as much as possible of all the suitable habitat in order to check for the presence of animals and to assess their numbers (Fig.2). For this I used the evidence of sighting, tracks and droppings, as well as a feature unique to regions where Tibetan Buddhism is practised. This involves the utilisation of the horns of wild and domestic animals as votive offerings, placed on cairns at significant places along major routes. The piles of horns may number several hundred and by their condition many clearly date back at least several decades, and they may provide additional evidence on the past and present occurrence of a particular species in the vicinity. In addition I interviewed a total 87 local people in 27 villages lying within or adjacent to urial range to obtain information on past and present number.

The field work was carried out during three visits to Ladakh. Some of the original reconnaissance work on the habitat was done during the summer of 1980; the rest, and the detailed surveys, were carried out from January to May 1981, and from October 1981 to February 1982. In all 138 days were spent in the field, plus a further 25 days on two visits to Zaskar. I chose winter for the bulk of the fieldwork since at that season animals concentrate in smaller areas and tracks are more obvious in snow. Young animals are clearly distinguishable from adults.

George B. Schaller et al., 1987. Large Mammals in
China Biol. Cons. 42 : 53-71

Methods

Two kinds of survey were conducted: transects, often along valleys, during which we checked on the status of wildlife by looking for spoor and interviewing local people;

and counts of wild ungulates and quantification of carnivore spoor in selected mountain blocks. In the latter, an attempt was made to obtain a total count of animals by surveying all drainages and scanning all slopes within areas that varied from 75 to 850 sq km in size. Survey blocks were not selected at random. All areas that might harbour Marco Polo sheep were checked (Areas 1-3 in Fig. 1), and one block in each of 4 major drainages (Areas 4-7) was selected.

On spotting an ungulate herd, we counted the number of individuals and attempted to determine age and sex, the latter often unsuccessful because Marco Polo sheep, blue sheep, and ibex were often found, especially around camps of pastoralists. Annual growth segments were measured and age at death was accurate for males but not females (Geist, 1966).

Carnivore tracks are often difficult to detect without snow cover, but some spoor is conspicuous. Brown bear excavate burrows in pursuit of marmots *Marmota caudata*. Snow leopard make characteristic scrapes - by raking hind-paws on the ground - at conspicuous locations such as on mountain passes and at the base of cliffs. To ascertain relative snow leopard abundance, we counted all scrapes and quantified valley bottoms with a width of about 25 m or less to permit easy search of both sides. Travel distances on ridges and in valleys were estimated.

Paul Wilson, 1981. Habitat Utilisation by Blue Sheep
Biol. Cons. 21 : 55-74

Methods

The observation methods used were essentially the same as Schaller (1973, 1977) and Wegge (1976). The census method consisted of searching south-facing alpine slopes with 8 x 30 binoculars and a 15-60 x zoom spotting scope. The animals were approached on foot, but due to disturbances by trophy hunters, and domestic livestock, observation distance varied from 200 m to 2 km.

P. Wegge, 1979. Population of Blue Sheep in Nepal
J. Asian Ecology 1 : 10-20

Materials & Methods

The field work consisted of a major four-month foot expedition from March through June 1975 and shorter field trips in November 1974, October/November 1975 and in April 1976, totalling roughly 24 weeks.

All potential wild blue sheep habitats were sampled for total animal number and population composition. This was accomplished by systematically searching opposing mountain slopes from a distance with 8 x 30 binoculars and a 15-40X variable spotting scope. When sighted, a group was

normally stalked within shorter viewing distance for more precise observations. Camp was moved every 3-5 days to visit all sub-valleys possibly inhabited by sheep. Animals were classified as lambs, yearlings, adult ewes and three classes of males; "trophy age rams" (fully grown males with an estimated horn length of at least 45-50 cm, horns curving noticeably backwards, animals believed to be 7 years of 30-35 cm but curving only slightly backwards, presumably comprising the age classes of 4, 5 and 6 year old), and "young rams" (2-3 years old smaller males with horn size between an estimated 15 and 35 cm). The horn length criterion related to age was established on the basis of a few sample specimen collected in the field and measured and aged according to Geist (1966) and Hemming (1967). When estimating population composition, only groups where all members could be classified were used.

G.B. Schaller, 1973. Observations on Himalayan Tahr
JBNHS, 70: 1-24

Population Dynamics

Tahr were difficult to census because they were often out of sight in thickets. Although I often scanned the slopes of the Kang Chu Rongshar, and upper Bhota Kosi valleys, tahr were seldom seen, suggesting that they were scarce there. But there was one cliff along the Bhota Kosi, a huge pyramid-shaped one, over 1 km long at the base and some 1000 m high, on whose face I readily found tahr. At least 45 tahr frequented this cliff, and, assuming a few were overlooked, the total was probably around 50.

Michael J.B. Green, 1987. Ecological Separation in
Himalayan Ungulates. J. Zool. 1.1 693-719
(Musk Deer Mainly)

Population Size

Censuses were conducted in spring and autumn, summer and winter being unsuitable seasons for such work because of adverse climatic conditions. The study area was subdivided into several blocks using topographical features, such as ridges and streams, as boundaries. Blocks were surveyed sequentially and within a two-day period by up to 12 men, in line abreast and spaced at intervals of 30-50m. Also, several men were positioned strategically above the tree-line in order to co-ordinate the census and to spot any animals which otherwise might have been flushed undetected from the block. Drives were relatively silent, rather than noisy, so as to maximise the chance of an animal being seen before it was flushed. Duplicate records, arising from the same animal being seen in several blocks, were minimised by conducting drives in directions which tended to flush animals out of the study area rather than into adjacent blocks.

A register of known individuals provided an alternative means of estimating population size. Individual recognition

was based on a knowledge of the sex and stage of maturity of an animal within the same locality. There was little cause for confusion as species occurred at low densities and, apart from sambar, appeared to have small ranges.

B: Estimates of Density for Himalayan Larger Mammals: A Preliminary Compilation

Introduction

One of the problems of working with Himalayan wildlife is the lack of information on their patterns of abundance. How common is "common"? How rare is "rare"? The J & K Wildlife Department in one of the very few publications on Himalayan wildlife numbers tells us that in 1979 Brown Bear were "common" and Ibex were "abundant" in the 200 sq km Rangdum Wildlife Reserve in Kargil. I do not know how to interpret this. If someone said to me "There are 0.5 brown bear per sq km in this reserve", I would not know if this was high, normal or low. Should I cheer or worry for its survival? There are no other data by which I can make comparisons. If a wildlife warden actively conserves an area for 10 years and at the end of it he has only 2 bharal per sq km what should he think? Is this normal maximum density or is it still very low and he must redouble his efforts? I hardly know!

In this appendix I bring together what published material I can find to illustrate the pattern of abundances of Himalayan large herbivores. This may help our management efforts in that we know what we could expect!

The Data Set

Density estimates for Himalayan animals are subject to a great many potential errors:

1. Methodologies are often crude, based on rapid survey, not on detailed study.
2. Maps may be poor or unavailable, which means that area estimates may be faulty. Flat projections of area for mountainous regions may give overestimates of real density.
3. Himalayan species may have definite habitat preferences, and these usually vary seasonally. Crude density estimates (population total size divided by total area) may greatly distort the true situation. For an example; if a 100 sq km area has 50 bharal, the crude density is 0.5/sq km. But if 50 sq km is rock and ice, then the potential habitat or ecological density is 1.0/sq km. If bharal use only north facing slopes then real density on optimum habitat may be 2.0/sq km. If they descend to valleys below 3,500 m in winter, then density there could be 10/sq km or more! Most data in this report are necessarily crude data.

When a wildlife density figure looks low, it may be due

to a shortage of suitable habitat, over-hunting or massive competition from domestic stock. Abundance data therefore need considerable qualification as to what they really are, and what they indicate about population status.

Data Sources

Very little information on numerical status or scales of abundance is available from the management agencies (J & K Wildlife Department is an honourable exception !). Most data comes from either long term biological study e.g. Michael Green in Kedarnath; detailed surveys e.g. George Schaller in Nepal and Pakistan in the 1970s, and again in China in the 1980s, or reconnaissance & compilation, e.g. Mallon on the urial, Green on goral and serow.

Conclusions

What conclusions can we draw from this set of data ?

- Densities are low compared with tropical communities.
- Maximum values of 12-15 animals per sq. km. for some species may be achieved in intensively managed well protected sites with presumably a low proportion of barren ground e.g. Ibex in Europe. Note the high figure for urial in a well protected princely estate in Pakistan.
- Typical values from the Himalayan studies are 0.2 to 3 per sq km for most species. These are from protected areas.
- Values from reserved forests will be very much lower than that for protected areas.
- Low density populations give especial problems for conservation. Protected Areas have to be large to include populations big enough to maintain long term viability. Five hundred bharal may require over 250 sq km of protected area at typical densities!

Species		Area	Density/sq km	Notes
Chamois	Rupicapra	Spain	14	Best Habitats
		Italy	7	Full Protection
Ibex	Capra	Terstei, USSR	3	Optimum Habitats
		Pamirs, Afghanistan	4 - 11	
		Caucasus, USSR	11 - 15	
		Spain	2 - 13	
		Italy	4	Full Protection
		Swiss Alps	4-9	Hunted
		Chitral, Pakistan	0.2-2	Hunted
		Kanji, J&K.	2.2	
		Bood Kharbu, J&K.	1.3	
Himalayan Tahr	Hemitragus	New Zealand	4.5-6.8	Introduced.
Musk Deer	Moschus	Gulmarg	<0.4	
		Kedarnath	3.2	Best area studied !
Hangul	Cervus elaphus	Dachigam	6 - 7 20 - 25	Overall range. Winter range.
Shou	Cervus elaphus	Extinct in India?		

Species		Area	Density/sq km	Notes
Sambar	<i>Cervus unicolor</i>	Kedarnath	- 1.1	Below 3000m.
Blue Sheep	<i>Pseudois</i>	Shang, J&K	3	
		Hemis, J&K	2 - 3	
		West China	0.2-2.2	
		North China	< 1	
		Nepal	0.8-1.3	
		Nepal	1.9-2.7	
		Near Indus, J&K	3.1	1979
Urial	<i>Ovis orientalis</i>	Hemis Rumbak } Hemis Markha }	<0.2	
		Baluchistan	0.8	
		Ladakh	0.7-1.2	
		Kalabagh, Pakistan	10-12	Optimum habitat.
Argali	<i>Ovis ammon</i>	North China	2 ?	
		West China	0.2	
Tibetan Wild Ass	<i>Equus hemionus</i>	North China	1.5?	Population in East Ladakh & N. Sikkim
Tibetan Antelope	<i>Pantholops</i>	North China	3-4?	Seasonal immigrants to Indian territory
Tibetan Gazelle	<i>Procapra</i>	North China	< 1.?	
Goral	<i>Nemorhaedus</i>	Kedarnath	2.6	
		Banog Mussoorie	5?	
Serow	<i>Capricornis</i>	Japan	1.5-10.0	
		Kedarnath	1.6	
		Lower Dachigam	0.6	
Takin	<i>Budorcas</i>	China	5+	Herds of up to 300 in Arunachal.

5.5 PATTERNS OF UNGULATE DENSITY IN PENINSULAR INDIA

Density Data for Ungulates in Peninsular India

Species / Area	Size km.	Density/ sq km
Elephant		
Mudumalai Bandipur Complex	2200	0.6
Kaziranga Total (seasonal)	378	2.2
Rajaji Total	850	0.4
Corbett Total	521	0.3
Gaur		
*Parambikulam (Deciduous Forest)	100	5.0
Kanha Total	940	0.56
Tadoba Total	117	1.9
*Melghat Total	1597	0.99
*Bori (Churna Area)	100	6.00
Nilgai		
*Sariska (Haripur scrubland)	11	25.0
Panna Total	501	4.4
Ranthambore Total	414	1.2
Gir Total	1412	1.2
Blackbuck		
Velavadar, Gujarat	c30	50+
Chinkara		
*Bishnoi areas, Jodhpur	c60	7.3
*Gir East	400	2.8
*Panna Total	501	3.3
Ranthambore Total	414	0.7
Chousingha		
*Gir Total	1412	1.1
Panna Total	501	0.4

Species / Area	Size km.	Density/ sq km
Swamp Deer		
West Kanha Meadows	c20	25
*Dudhwa Grassland (East)	19	16
Kaziranga Total	378	1.9
Hog Deer		
Kaziranga Total	378	18.3
Dudhwa Grasslands Total	c60	20
Corbett Total	521	1.1
Spotted Deer		
Bandhavgarh Total	448	19.7
*Gir Total	1412	55.62
*Sariska Valley	c20	30
Kanha West	c500	30
Tadoba Total	117	10.6
Corbett Total	521	28.3
Barking Deer		
*Melghat Total	1597	0.79
Corbett Total	521	1.4
Sambar		
*Gir Total	1412	2.1
Kanha Total	940	2.0
Corbett Total	521	5.1
Tadoba	117	1.1
*Sariska Core Zone 1	c200	9.0
*Bandhavgarh Total	448	4.1
Ranthambore Total	414	5.7
*Melghat Total	1597	0.79
Wild Boar		
Ranthambore Total	414	1.4
Melghat Total	1597	0.6
Tadoba Total	117	3.6
Corbett Total	621	4.7
Gir Total	1412	0.9
Bandhavgarh Total	448	3.6

Note With few exceptions (marked *) data are taken from traditional Forest Department census operations. Figures come with no estimates of accuracy or confidence limits, and often with no details of methodology. These density levels should be used with caution and serve only to show the possible level of animal abundance that could be expected. Those marked (*) are censuses with a detailed methodology and ability to calculate estimates of accuracy and precision.