*National Training Programme on*

# Research Techniques in Wildlife & Habitats

## Training Manual

**January 08-12, 2021**
*Mollywood the wanderers Tent resort*
*Sana caves and Forests,*
*Eastern Gir*

**WCB Research Foundation**
*Adding science to the conservation*
www.wcbresearch.in

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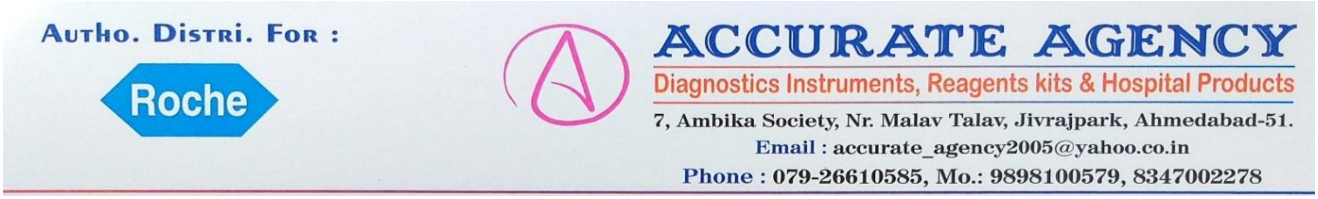
***~WCB Research Foundation***

# *We are grateful to Accurate Agency*




**About Us**

*We, Accurate Agency with wide experience in providing laboratory and diagnostics solution since last 18 years. We believe in providing best solution with costumer centricity attitude.*

**Product portfolio**

*We are authorized channel partner for MNC like Roche and also providing solution in whole genomics and proteomics area. We provide genetic lab set up which includes RTPCR techniques to sequencing based products. We also provide fully automated machines with highly sensitive and robustness from Roche to reach the maximum throughput.*

*We also provide consulting services with our dedicated and highly qualified team for NABL lab set up.*

*We also provide all laboratory materials including RTPCR machines, Biosafety cabinets, full research lab and diagnostic lab set up solutions and also miscellaneous items like Pipette and etc.*

*We believe in providing best and reliable healthcare solutions and laboratory solution.*

## *WCB Research Foundation*

*Adding Science to the Conservation*

*WCB Research Foundation is a nonprofit section 8 company registered under the Company's Act (2013), Government of India. The foundation was established on September 10, 2020 with the goal of accelerating action oriented research and enhancing the capacity of conservation professionals for effective research in the field of wildlife and conservation biology. We are committed to science based conservation and outreach activities through research and development.*

*The major thrust areas of research at WCB are mammalian ecology and behaviour, habitat evaluation and modelling, wetland biology and monitoring, biodiversity monitoring and environmental biotechnology. We are also engaged in the consultancy work such as biodiversity monitoring, soil and water testing and Green audits.*

*Our foundation is supported by various national and international organizations and we have active collaboration with several reputed institutes and organisations such as, Gujarat Forest Department, Gandhinagar, Wildlife and Conservation Biology Research Lab, IUCN Bear Specialist Group, University of Richmond (USA) and the Institute of nature conservation, Polish Academy of Sciences, Poland.*

*We welcome scientists and faculties for collaboration and joint research work, students for their internship, dissertations as well as voluntary work with WCB fellows.*

## *Objectives:*

- ✓ *To conduct and promote research and monitoring on wildlife and habitats*
- ✓ *To promote awareness for wildlife in society*
- ✓ *To organize scientific gatherings and capacity building programmes, Outreach of scientific knowledge on wildlife and conservation*
- ✓ *To generate the skilled human resources through research training, internship and dissertation*
- ✓ *To assist the local government and policy makers for wildlife management and habitat conservation*

## *Governing Council of WCB Research Foundation*

| | | | |
|---|---|---|---|
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| 2 | Dr. Hardik Patel | Asst Professor | Parul University, Vadodara |
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## WCB Vision

### || आत्मवत् सर्वभूतेषु ||

**"जो सब प्राणी को स्वयं की भाँति (आत्मवत्) देखता है वही पंडित है।"**

***The one who sees every creature of nature as his own (self-self) is the real scholar***

# 1 Basics of Wildlife and their Management

It is important to identify and define what we mean by the term "wildlife" before we can answer the question, "What is wildlife management and conservation?" Early definitions of wildlife focused on wild animals (undomesticated free-ranging animals) that could be hunted for sport or food therefore, the early definitions restricted the term wildlife to **vertebrates**. From that time forward, the message has been clear: there is a separation of those organisms termed wildlife, not only from other vertebrates, but most certainly from other groups of lower animals and plants.

Much has happened in the field of wildlife management since early times, and this is reflected in new definitions of wildlife based on a more holistic viewpoint. The beginnings of this new viewpoint of wildlife began in the 1960s. Wording in the Endangered Species Act of 1973 recognized fish and wildlife as any member of the animal kingdom, including without limitation any mammal, bird, fish, amphibian, reptile, mollusk, crustacean, arthropod, or other **invertebrates.**

From a purely objective standpoint, wildlife should include all animals and their associated habitats. If we are to look at the big picture, it seems unnecessary to define the term wildlife along the usually rigid and nonfunctional lines of a **taxonomist.**
Further, the relationship of an animal to its habitat (including competitors, predators, prey items, vegetation, and soil) is so interconnected as to add confusion in attempts to restrict the term wildlife.
***"A definition of wildlife should include all living organisms out of the direct control of man, including undomesticated or cultivated plants and animals."(In other terms "Neither domesticated nor cultivated")***
Although it may be inappropriate to restrict wildlife to a few kinds of organisms, common usage, public perceptions, funding allocations, and history have resulted in a practical definition of wildlife as undomesticated free-ranging vertebrates. Furthermore, because of professional distinctions, fish are generally excluded from the definition of wildlife. The definition of **wildlife** is left as essentially undomesticated, free-ranging terrestrial vertebrates (reptiles, amphibians, birds, and mammals).

The overwhelming preponderance of research and management efforts, as well as public attention, has caused the definition of wildlife to focus on birds and mammals.

### *What is Wildlife Management?*

Now on to the question, "What is wildlife management?" The definitions of wildlife management are about as numerous as authors and professional biologists. There are some differences, to be sure, but three common ideas are present in every definition of **wildlife management**, including:

1. efforts directed toward wild animal populations,

2. relationship of habitat to those wild animal populations, and

3. manipulations of habitats or populations that are done to meet some specified human goal.

Early wildlife biologists viewed wildlife management as the art of making land produce adequate game for recreational use (hunting, fishing, or trapping). Later definitions emphasized wildlife management as the science of manipulating wild animal populations and their habitats for specific human goals. Current definitions stress wildlife management as applied animal ecology that benefits the habitat and both wildlife and human populations.
Wildlife management can be a complex process (Figure 1) whereby a landowner or biologist:
☐ conducts habitat and wildlife population inventories and evaluations; and
☐ determines what people desire from the wildlife resource and directs management eforts to meet this goal.

The eventual outcome in meeting desired management goals is accomplished by:
1. Manipulating the habitat,

2. Manipulating the wildlife population, and

3. Managing people.

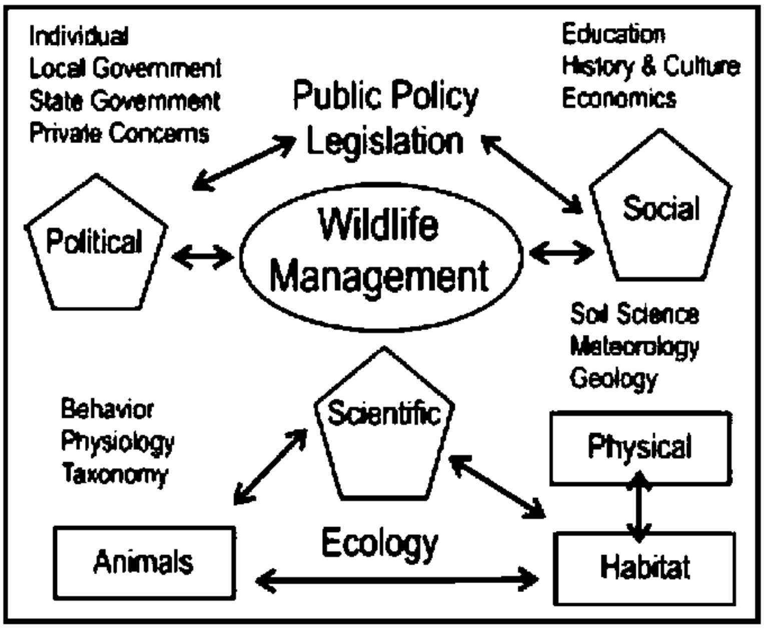


***Figure: 1 The process of wildlife management***

***Preservation, Conservation, and Management: What is the Difference?***

Let's now examine the differences between management, conservation, and preservation, because many people mistakenly confuse wildlife management with wildlife preservation.

**Conservation** is an effort to maintain and use natural resources wisely in an attempt to ensure that those resources will be available for future generations. Wise use of resources could vary from actively managing white-tailed deer populations by hunting to protecting and preserving spotted owl populations and habitat.

**Preservation** is a component or part of conservation in which natural systems are left alone without human disturbance or manipulation. Preservationists feel natural resources should be protected, unspoiled, and untouched by humans. The goal of preservation is often maintaining the integrity of the ecosystem as exemplified by nature preserves or wilderness areas.

**Passive management strategy** is sometimes used in wildlife management when wildlife populations dwindle to the point they are in danger of extinction. The passive management strategy for red-cockaded woodpeckers in South Carolina is to alter traditional timber management to ensure breeding and foraging habitat.
It is important to note, however, that an undisturbed ecosystem is not necessarily a stable one. Natural changes in the plant community constantly create different habitats for different species of wildlife. As the system changes over time, conditions may not remain suitable for the continued existence of some wildlife species in that community.
As a regenerated forest is allowed to mature, for instance, the presence and abundance of bobwhite quail will decline because the habitat is no longer suitable for them.

**Management** is also a component of conservation that usually means controlling, directing, or manipulating wildlife populations and/or their habitats (active management strategy). Wildlife managers usually seek to:

1. Increase a population (by providing key habitat components such as food, shelter and water);

2. Decrease a population (by harvesting deer when they are damaging orchard trees or soybean crops); or

3. Stabilize a population so that individuals can be removed on a continuing basis, making sure that enough individuals remain in the population to replace those that are removed (**sustained yield**).

There are two different approaches to managing wildlife. The first approach is to provide as varied a habitat as possible in an attempt to support as many different wildlife populations as possible. This is called the **species richness approach** to managing wildlife. Under this system, landowners would try to manage their property to provide a mixture of areas in different plant stages, areas with large amounts of edge (area where 2 habitats meet) interspersed with some unbroken tracts of forest, and forested areas with vertical layering of trees, shrubs, and broadleaf weeds.

The second approach to managing wildlife is called the **featured species approach**. The goal of this approach is to provide habitat for one selected (featured) species. The key to featured species wildlife management is to identify the precise habitat requirements of the featured species and select management practices that provide the requirements that are in the shortest supply.

**Options for Wildlife Management**

Any discussion of wildlife resources must begin by recognizing the potential for managing for a variety of wildlife species. These include threatened and endangered species, and even nuisance species. Managing the wildlife resource as the primary objective requires, in some instances, that other resources be managed differently. For example, timber harvests would be designed primarily to improve wildlife habitat, with maximum wood production being a secondary benefit. In this case management strategies could include or accomplish the following:

☐ Create, enhance or improve sufficient habitat to support suitable populations of desired wildlife species;

☐ Maintain healthy populations in a manner consistent with habitat carrying capacity;

☐ Provide diverse and abundant populations of desired threatened wildlife species, particularly those that are dependent on woody forest and

☐ Manage habitat and populations to protect flora and fauna listed as threatened or endangered.

The key is that all resource management decisions are based on creating and maintaining sufficient habitat.

**Research in Wildlife PA'S**

Ministry of Environment, Forest and Climate Change has received detailed guidelines for scientific research in wildlife PA's. It is aptly recognizes that information generated by scientific research in PA's would be useful for taking appropriate conservation and management actions. As enunciated in National Wildlife Action Plan (2002-2016), research projects having the objective of measuring biological diversity; monitoring the status of indicator/ flagship/ threatened species of flora and fauna, and breeding biology, is to be given priority. Encouraging multi-disciplinary integrated research encompassing scientific and socio-economic aspects related to PA management has also been accepted.

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# 2 Monitoring methods for terrestrial vegetation for wildlife habitat assessments

There are many parameters used to quantify the vegetation especially for wildlife management and monitoring of habitats. Such parameters are also useful to study animal-habitat interactions, impact assessment and survey and quantifying wildlife habitats. These parameters are also used as baseline information for future monitoring. This whole exercise requires a careful sampling of vegetation and their analysis. Wildlife habitat data are generally collected for academic research as well as protected area or forest managers for both experimental and monitoring purposes respectively.

The techniques here we are using are largely adapted from the traditional plant ecology, forestry and wildlife habitat study institutes; however, for rapid monitoring and assessment as well as its effective utilization, it is necessary that the sampling methods must be cost effective, explicit and widely acceptable.

Some of the most commonly used and effective sampling methods for terrestrial vegetation i.e. trees, shrubs and herb layer are reviewed and compiled here. I welcome your feedback on the applicability and improvements of these methods.

**Major attributes of vegetation and their significance in wildlife habitat monitoring:**

All the attributes of vegetation can be categorized into two aspects viz. structural and functional. The structural includes the life form and arrangements of plants and the functional includes weight, shape, size and number of individual species. Following are the major attributes of vegetation for wildlife habitat studies.

1. Density, 2. Cover, 3. Frequency, 4. Biomass and 5. Diversity

| **Major attributes of vegetation, their wildlife applications and study method: *No*** | ***Vegetation attributes*** | ***Wildlife Applications*** | ***Study methods*** |
|---|---|---|---|
| 1 | Density | Correlation to animal populations, Forage management, Regeneration of desired species | Quadrates, Belt transect, PCQ, Plot less and nearest individual method |
| 2 | Frequency | Relative abundance of desired species, Forage quality, Successional trends | Point intercept, Quadrates, Line intercept |
| 3 | Canopy cover | Thermal, Escape, Resting, Roosting and other cover requirements | Point and line intercepts, Ocular estimation, Densiometer |
| 4 | Foliar cover (Leaf area index) | All as per 3 and Correlation with insect abundance | Line intercept Cross wire sighting |
| 5 | Basal cover | As above (3 and 4) | Quadrates, PCQ and Plotless |
| 6 | Ground cover | Interpret community impact assessment | Point intercept Grid–quadrate frame |
| 7 | Production | Forage quality and quantity Suitability, Season of use, Phenology | Clipping & weighing Forage volume estimation Double sampling |
| 8 | Species composition | Forage quality Species diversity | Species enumeration Releve' method |
| 9 | Structure | Potential habitat Nesting /resting sites Other cover requirements | Bisects Life form study |

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# 3 The concept of habitat

***By: R. H. YAPP***

## Historical

We are often reminded, sometimes with an air of patronage, sometimes in tones of apology that ecology is yet in its infancy. But already it has left the cradle behind, and is now generally acknowledged to be a sturdy stripling, full of the vigour and the promise of youth. Naturally it has many of the faults as well as the advantages of youth. But maturity will come in time, and when that time arrives, we cannot doubt that botanical thought and knowledge will be the richer for the pioneer work of present day ecologists and their predecessors.

As must inevitably be the case, especially during the youthful phase's 01 any subject of study, the aims and concepts of ecology have been much discussed and repeatedly defined. Some of these concepts are, at all events for the time being, generally accepted and understood, while others are still a matter of controversy. As Tansley wrote (27, p. 120), " We must never conceal from ourselves that our concepts are creations of the human mind which we impose on the facts of nature, that they are derived from incomplete knowledge, and therefore will never early fit the facts, and will require constant revision as knowledge increases."

Curiously enough, the concept of habitat, one of the oldest and most fundamental concepts of plant ecology, though in constant use, has been less rigorously examined than some; not so much because it has escaped notice, as because it has usually been taken very much for granted. Ecological literature contains many definitions of "the habitat," but so far as I know no one has yet attempted critically and analytically to examine the concept as such. In this address I propose to make such an attempt. If I succeed in focusing attention on the subject, and perhaps in some slight measure in resolving the ambiguity which still obscures the concept, my object will have been achieved.

The dictionary meaning of the word habitat is "the natural place of growth or occurrence of a species....Dwelling place, habitation[1]." A habitat then is a place of abode. In this sense it is the equivalent of the Greek *oiKos,* and more or less of the English *station*. Warming (31, p. 131) uses habitat in this sense when he speaks of "the ecological factors...that prevail in the *station* or habitat." Gams (12, p. 307) has recently urged that the use of the term *Stantdort* should be similarly restricted. Most ecologists; however, extend the use of the term habitat so as to include not only the abode itself, but also, in so far as they affect the inhabitants, the conditions obtaining in the abode, i.e. the ecological factors. In this sense habitat corresponds more or less closely to the English *environment,* or to the word oilier as used by French, and *Stondort* by many German writers. This extension of the meaning of the term would appear both legitimate and natural, for it is the habitat factors which give importance to the habitat. It is in this extended sense that I shall use the term in my address. Even so, the usage varies according to the concept in the mind of the individual author, and this in turn depends very much on the nature of the investigations on which he is engaged. In other words, hitherto the concept of habitat has been largely subjective. This ambiguity has been commented on by various authors. For example, Clements (4, p. 358) refers to the application of the term habitat as "completely a matter of individual opinion." Nichols (19, p. 306) says it "has been applied somewhat loosely." Pavillard (20, p. 5) remarks on "l'ambiguité bien connue de la notion de Standort.' "

On analysis, it may be seen that a number of distinct ideas have been introduced into the concept of habitat.

**(1) The area idea of habitat.** Probably most ecologists have conceived of habitats as occupying more or less definite and extensive areas of the earth's surface. Clements (3, p. 18) wrote in 1905, "The habitat is the sum of all the forces or factors present in a given *area*[2]*."* Flahault and Schriiter (10, p. 24) defined habitat as including "everything relating to the factors operative in a *geographically defined locality*[2]*,* as far as these factors influence plants." Nichols too (19, p. 306) speaks of "*any unit area*[2]," and so on.

**(2) Uniformity of life-conditions in habitat.** Essential uniformity of conditions within a habitat is insisted on by some authors. This idea frequently enters into definitions of the plant association, the habitat being regarded as the physical counterpart of the association. Thus Flahault and Schriiter (10, p. 25) define the association as "a plant community of definite floristic composition, presenting a uniform physiognomy and growing in uniform *habitat-conditions."* Nichols (19, p. 307) says, "The habitat may be further defined as any unit area iñ which the combined influence of climatic, edaphic and biotic factors is *essentially uniform throughout*." Cowles (7, p. lll), again, speaks of *"similar life-conditions*." Du Rietz (9, p. 243), on the other hand, is more impressed with the *diversity of conditions* under which plant communities can exist, and points out that every plant association, like every species, has a definite ecological amplitude. Tansley (27, p. 128) too mentions the *range of conditions* under which the community can exist.

**(3) Change and development in the habitat**. The authors previously quoted have evidently, for the most part, conceived of the habitat as that o1 the plant association. But with the recognition of the principle of plant succession, a tendency to extend the concept so as more definitely to include the element of time as well as space, began to manifest itself. Moss (18, p. 36) introduced the idea of a succession of associations *within the same habitat*. This was adopted by the British Vegetation Committee (see Flahault and Schroter, 10, p. 16), and used in Tansley's *Types* (26, p. 4). According to this idea, a plant formation consists of a series of natural phases of vegetation occurring "upon a habitat uniform in its fundamental characteristics." Subsequently, however, the idea of uniformity was abandoned, as it was realized that the habitat is continuously changing during the course of succession (Tansley, 27, pp. 140—1). But the element of time was retained. Later, Clements (4, pp. 357—8) suggested that "the final and definite form of a concept of the habitat" might introduce the idea of change and develop ment. He regarded the habitat as the counterpart of the sere rather than the association, and says, "the habitat ie itself marked by development in the same way that the formation is."

**(4) The habitat of the individual.** The synecologist has, naturally enough, interpreted "the habitat" according to whether he was primarily concerned with the plant association or with plant succession. But as soon as ecological research becomes intensive rather than extensive, one becomes impressed by the diversity rather than the uniformity of life-conditions within the common habitat of a plant association. The autecologist realises the fundamental importance of the habitats of the varied growth-forms, or even of the individuals, of which the plant community is composed. Warming (30, p. 119) and others have emphasized this point of view. As regards fen vegetation I showed (Yapp, 34, p. 306) that plants growing side by side were not necessarily subjected to the same conditions. Later (Yapp, 35, p. 860) I pointed out that the physiological problems of individual species might be very diflerent even when growing in the same general habitat. Cockayne (6, p. 6) came independently to a similar conclusion. In a letter (1913) to me, which I venture to quote, he said, "it is not the so-called 'habitat' of the association that we have to consider, but the environment of the individual, an altogether different matter." **Kraus** studied intensively for eleven years the habitat variations occurring within a limited area. He showed definitely that the immediate environments of plants growing close together, *within the same* general habitat, may vary within wide limits as regards:— percentage of calcium carbonate, temperature, water content, atmospheric humidity and wind. As Stiles, in a review of Kraus' book (25, p. 258) re- marked, " This view of the habitat as varying much over a very small area, and so necessitating the investigation of the habitat of a single plant rather than that of the whole plant association, should surely be of great help in the future in the elucidation o1 the many and little understood problems of plant ecology."

Nichols, and especially Gams have treated the habitat question from a broader point of view than the majority of plant ecologists. Nichols (19, pp. 307 *et seq.)* regards similar habitats within a climatic region, whether occupied by precisely the same vegetation or not, as equivalent to one another, and as belonging to a common *habitat-type*. Further, he introduced the term *habitat-complex,* to indicate "a group or series of habitats which occupy a unit area and are alike with reference to one or more habitat factors." But "the habitat" itself he regards as that of the plant association. Gams (12, pp. 306 *et seq.)* rightly insists that there may be various kind of habitats, but proposes—unfortunately in my opinion—to apply to each of them a separate, unconnected term. The term *Standort* (our habitat) he would restrict to the larger unit areas, such as those occupied by plant associations. To the place occupied by an individual flowering plant he gives the term *Lebensravm;* while the abode of a minute eryptogam, in which the habitat factors are uniform, he calls *Lebensort*. As living cryptogams may occupy the places of portions of larger plants, e.g. roots, stems or leaves, hams concludes that a *Lebensraum* consists of several different *Lebensorten.*

To sum up, most authors have interpreted or defined "the habitat" subjectively, i.e. from the point of view of their own particular work. From their writings, few would appear fully to have realized that there may be various grades or classes of habitats. To what extent these apparently divergent views regarding the concept of habitat are really antagonistic, or merely complementary, we must consider later.

**The factors of the habitat.**

Of the many factors which make up the environment it is obvious that only those which influence, directly or indirectly, the physiological processes of plants, are of importance to plant life. Further, a factor may he of importance to plant like, and yet have little or no geographical significance; such a factor is gravity. It is those factors alone which affect the physiological processes of plants, and at the same time are distributed unevenly—either qualitatively or quantitatively—in nature, that can act as determining factors in plant distribution. It is these factors with which we, as ecologists, are mainly concerned.

Various classifications of ecological or habitat factors have been proposed. The following, though criticised by several authors, has been widely accepted:—

A. Physical (including chemical) factors.

1. Climatic.
2. Edaphic.
3. Topographic or physiographic.

B. Biotic, biological or organic factors.

It may be pointed out that the habitat factors are often closely interrelated, and that no hard and fast lines can be drawn between the different groups. Some factors, e.g. mineral salts and light, may be mainly or exclusively either climatic or edaphic, while others are common to the two groups. Water, for example, is such a common factor. In its aspects of precipitation and atmospheric humidity, water is called a climatic factor; while so tar as the water-content of the soil is concerned, it is an edaphic factor. Clearly, from the point of view of the physiology of the plant, these are merely different but inter-related aspects of one factor, i.e. water. Similarly, soil and air temperatures are but diflerent aspects o1 the same factor.

Topographic and biotic factors, though frequently of great importance, are usually indirect in their action, influencing plants by modifying more direct factors. Thus mountain ranges influence climate. Local differences of aspect or angle of a slope affect temperature, light, wind and drainage. Associated plants modify light and atmospheric humidity for each other. Nitrifying bacteria, earthworms, etc., exert a far-reaching influence on the chemical and physical characters of the soil, and so on.

From the point of view of direct effect on the plant, we can recognize, out of the numerous factors of the habitat, a few, very few, *fundamental* or *basic factors,* or groups of factors. Of these the most important are (1) water (soil and atmospheric) ; (2) gases used directly by plants (especially oxygen and carbon dioxide) ; (3) nutritive salts and certain other soluble soil sub-stances; (4) light, and (5) temperature (of soil and air). With few exceptions these basic factors are of fundamental importance in the life-processes of plants, and may also act as *differentiating or muster factors* (cf. Tansley, 56, p. 5). All, however, have not the same geographical significance. Compare for instance carbon dioxide and oxygen. Both are of great importance to green plants, and the proportions in which they occur in the atmosphere are fairly constant the world over. But while carbon dioxide is of little value as a geographical factor, oxygen, on account of its slight solubility in water, acts as a master factor in the ease of habitats characterized by excess of '**water'.** The majority of factors other than the basic factors mentioned are either subordinate in importance or indirect in their effect on vegetation. As a rule, in the investigation of habitats attention would naturally be focused first on the more important'basic factors.

In laying stress on these basic groups of **factors,** I wish to suggest a point of view rather than to propose a new classification. If we adopt the usual classification into climatic, edaphic, etc. groups, we should avoid the mistake of thinking in terms of plant organs rather than entire plants. Climatic factors do not affect merely the sub-aerial parts of plants, nor edaphic factors only the subterranean organs. Whether we are dealing with individuals or communities, it is ultimately the whole economy of the plants concerned that is affected by the habitat factors. We must regard the plant as a living whole, and should strive as far as possible to visualize the problems of the habitat as they are presented to the individual plant or plant community.

A concrete example may serve to illustrate my meaning. Consider the habitat problems of three associated plants, a tree, a small herb growing at its foot, and a minute alga attached to its trunk. The environments of all three plants fluctuate within wide limits with changes of season and weather; yet the three individuals are living under very different conditions. Take the factor of temperature, on which the rate of physiological processes so largely depends. So far as the alga is concerned, whatever the actual temperature may be, and however rapid the periodic fluctuations, at any given moment of time the temperature of the entire plant is approximately uniform. Now the temperature of the air changes more rapidly and violently than that of the soil, and the deeper the layer of the soil the more uniform the temperature. The twigs and leaves of the tree, therefore, will be subjected to much greater fluctuations of temperature than the roots. Moreover, the physiological processes o1 the tree, considered as a whole, are directly affected, not only by the absolute temperatures of air and soil, but also by the differences between the two, that is the ratio of air to soil temperature. In this respect the tree, compared with the alga, is a plant of extremes, and its habitat problems more complex. The herb, with its more sheltered shoots, and roots nearer the surface of the soil, is intermediate between the tree and the alga. If we consider further the question of water supply as well as other factors, we shall realize the vast difference between the habitat problems of our three associated plants.

I have of course selected an extreme case, but even in comparatively uniform types of vegetation, the problems of different growth-forms show similar diversity. The difference between these and more extreme cases is one of degree rather than of kind.

### 1. Growth-forms and the stratification of vegetation.

Warming and many other ecologists have rightly insisted on the importance the study of the growth- or life-forms of plants. Warming (31, pp. 140—1) even based his classification of vegetation units on growth-forms, a view sharply criticized by Tansley and Moss (cf. Flahault and Schroter, 10, p. 17, and Tansley, 27, p. 121). Whatever their value in this connection, there can be no doubt as to the great importance of growth-forms in the investigation of the physiological inter-relations of plants and habitat. This is, in my opinion, one of the most fruitful points of view from which the study of growth-forms can be approached. The special habitat problems of associated species are, as we have seen, closely bound up with differences of growth-form. In this connection I would urge not only that we should look upon the plant itself as a living whole, but also that the growth-form a plant should be regarded as including the entire plant, and not, as is often the case (e.g. Warming, 31, pp. 7 *et* deg.), the shoot-system alone. The root- systems of plants should not be neglected as much in the future as they have been in the past.

In the rather wide sense in which I am using the term (ct. Tansley, 27, p. 121), the growth-form of a species may either be more or less constant, or it may vary from time to time during the life of the individual. The former is frequently the case with lower organisms, the latter with higher plants. In the one case the habitat problems may be fairly constant throughout the life of the individual; in the other they may vary according to the stage of development, or even with the season of the year.

In the majority of cases a plant association comprises not only different species, but also a number of different growth-forms. The varying sizes of the component plants usually result in a more or less definite stratification or layering of the vegetation, though certain Thallophyte associations, in which the plants are small, may consist of a single stratum only. As a rule the number of recognizable strata increases with the size of the dominant species, as does also the number of growth-forms represented. In both respects the culminating point is no doubt tropical rain forest. But even in dwarf, comparatively homogeneous vegetation such as that of a ten, if we take growth-form as well as size into account, it may be possible to distinguish as many as five sub-aerial strata". In addition to this, the subterranean parts (roots, rhizomes, etc.) vary not only in form, but as regards the level they occupy in the soil. There is frequently as marked a stratification 01 the sub-terranean as of the sub-aerial organs (Yapp, 34, p. 308). The fact of stratifiation has, as we shall see, an important bearing on the habitat problems of species in a state of association.

## 2. Factor variation within the "general habitat."

We have seen that uniformity of like-conditions within the habitat of a plant association has been postulated by many authors. We must now enquire to what extent or in what sense such uniformity actually exists. It has of course long been recognized that ecological factors are distributed unevenly in nature, and that in a general way different types of vegetation are an expression of broad differences of habitat. Only comparatively recently, with the advent of intensive research, has much attention been paid to differences occurring within these "general habitats." Now, however, it is becoming increasingly apparent that in many, if not in all plant communities, the physical factors are distributed by no means uniformly within the space inhabited by the shoots and roots of the associated plants. In other words, in respect of the distribution of physical factors few, if any, habitats are really homogeneous. This lack of uniformity exhibits itself in various ways. For instance, in the existence of a certain range of conditions within the limite of which a particular association can exist (cf. Tansley, 27, p. 128). Or it may be due to minor local irregularities produced by, e.g. small differences of soil-level, aspect or slope. In addition to these variations in what we may call the *horizontal direction*, evidence is accumulating that as regards certain factors, a *vertical gradient* frequently exists, both in the atmosphere and in the soil.

So far as the atmosphere is concerned, it is probable that such a gradient, irregular it may be, exists in practically all markedly stratified vegetation, with regard to humidity, light, and perhaps temperature (cf. Yapp, 34 and Adamson, 1, pp. 353, etc.). Salisbury too has recently proved the existence of a vertical gradient of humus and acidity in certain dune and woodland soils. He suggests "it is not improbable that rooting depths are, in part at all events, determined by the acidity gradient described" (22, p. 297). Such differences in the vertical distribution of physical factors are in many cases largely due to biotic factors of the habitat, i.e. to the existence of the vegetation itself. As Gleason (15, p. 35) remarks, "The plant itself is in many cases the controlling agent in the environment;...and the physical environment is as often the result as the cause of the vegetation." Several authors have pointed out that topographic and other causes may give rise to local as distinct mom regional climates. A covering of vegetation may have a similar result, and it is not going too far to say that the smaller, subordinate species of an association may live in a climate differing in many respects from that of the larger dominant species'.

Looked at from this point of view, the "general habitat" of an association appears, on analysis, to be characterized by complexity rather than by homogeneity or uniformity. As the association develops, or as association succeeds association, plants with different needs will naturally, under the stress of competition, tend to sort themselves out according to local differences of conditions within the general habitat. Competition being keenest between species of similar growth-form and requirements, we may perhaps regard most plant associations as more or less "complementary," in the sense em- ployed by Woodhead (33, p. **345).**

Thus it may be just as true to say that the distribution of the component species within a plant association is governed by the local distribution of factors, as to say that the distribution 01 the association itself depends on the General distribution of habitat factors. Even if this is not true in all cases it certainly is true of many stratified associations.

The different species, be it observed, will not necessarily be found in situations where, in the absence of competition, they might fourish best. They will occur in those portions of the general habitat in which, taking all factors—physical, biotic, and even historical—into account, they can best establishes and maintain themselves. As Ganong (13, p. 342) puts it, "Any plant stands where it does for the reason that the physical demands made by the structure and habit it happens to possess overlap in some degree the physical conditions prevailing in that place, and the better they match the more nearly does the plant find its optimum, and the worse they match the more slender is the hold of the plant upon that place." Further, he points out that, "Ecologically speaking there are four critical periods in the like-cycle of a plant. These are (a) the germination of seed or spore, (b) the orientation of the seedling whereby the plant gains a grip upon its immediate surroundings, (c) the expansion of the adult, and (d) flowering or fruiting, or sporification. It is not enough that the plant can match an environment in three of these, it must match in all four."

The vexed question of the origin of " epharmony," i.e. of the agreement between plant structure and habitat, or even the degree to which such agree ment actually exists, lies entirely outside the scope of this address. What we are concerned with for the moment is the fact that the complexity of habitats, coupled with the peculiarities of the plants themselves, frequently result in the association of species of very dissimilar requirements. What becomes then of the "uniformity of life-conditions" within the common habitat of a plant association? Nature, as Tyndall once wrote (28, p. 264) "abhors uniformity more than she does a vacuum." In the sense of being. So to speak, of a homogeneous texture throughout, uniformity in the common habitat of a plant association cannot be said to exist. On the other hand, in the sense of either a similarity of life-conditions in corresponding parts of the general habitat, or the prevalence of a particular complex of factors (with a particular master factor) over a given area, we can speak of a degree of uniformity. I lay some stress upon this distinction, because arguments have sometimes been based on the assumption that plants growing side by side in nature are necessarily subjected to the same environmental conditions. Such arguments are fallacious, for they are based on wrong premises (ct. Kraus, 16).

**Biotic associations**

If we attempt to visualize even a single mixed, closed plant association, from the point of view of the relations of the plants to their habitat and to each other, we cannot fail to be impressed by the immense complexity of the problem. Yet the attempt may be useful, if only as a means of sounding the depths of our own ignorance.

In a limited space a number of sedentary organisms, belonging to different species, and of varied growth-forms, are crowded together. They are not only continually reacting on the habitat, but also, in different ways and degrees, interacting with each other. Competition, toleration; dependence, and in a sense perhaps even co-operation, are some of the elements of the problem.

But which of the interacting organisms shall we include in our conception of a plant association? Already this conception is widening. In addition to the sub-aerial portions of the higher plants, which were chiefly or alone taken into account by the older ecologists, increasing attention is being paid to subterranean organs and to cryptogams. Where shall we draw the line? Obviously, many soil organisms, such as soil fungi, the bacteria of decay and nitrifying bacteria exert a profound, even if indirect influence on the surface vegetation. The soil fauna too has considerable effect. Darwin showed the importance of earthworms, while Salisbury (22, p. 295) has recently found that they tend to reverse the normal acidity gradient of the soil. Protozoa (trophic amoebae) again, appear to aftect the numbers of bacteria in the soil (Cutler and Crump, 8, p. 21). Shall we then include animals and lower cryptogams as well as higher plants in the same associations? So far as the interactions of the organisms are concerned, it would seem probable that we may be justified in doing so. Unfortunately animal ecology as yet lags behind plant ecology. We do not know to what extent the limits of plant and animal communities coincide. If they are proved to coincide to any appreciable extent, we may have to revise our concept of the plant association. The prevailing concept more or' less seems to be that of a community of (mainly higher) plants living together in a habitat modified by the presence of other organisms, i.e. by biotic factors. It may be that in the future we shall have to replace this somewhat crude concept by what Vestal (29, p. 13) has called *" singte biotic associations."*

Vestal has formulated the hypothesis "that animals and plants in a given terrestrial environment are very intimately related; that plant and animal associations are co-extensive and to a large extent interdependent, the animals being entirely dependent upon the plants, speaking broadly, and the plants being partly dependent upon the animals." If this is true, we should be justified in grouping the associated plants and animals together on sociological as well as on physiological grounds. On this matter our ignorance is great, but the subject offers a promising field for investigation.

We may perhaps regard the organisms, both plants and animals, occupying any given habitat as woven into a complex, but unstable web of like. The character of the web may change, as new organisms appear on the scene and old ones disappear during the phases of succession, but the web itself remains. The physical environment as it were provides the stage on which the drama of organic life is to be enacted.

**The classification of habitats.**

We must now enquire whether it is possible to attain, for practical purposes, any measure of agreement regarding the concept of habitat. In the first place there appears to be every reason for agreeing that the term habitat should be taken to include the factors or conditions of the environment. Most authors already use it in this sense, and though literally it might be more correct to speak separately of habitat and habitat-factors, the single term is a convenient one. Apart from the factors, the habitat, from the point of view of ecology, is little more than an abstraction.

The real difficulty in defining and delimiting the habitat arises from the fact that the ecological factors are so numerous and so variable that their possible combinations are bewildering. In regard to habitats, as in so many other instances, nature draws no hard and fast lines. For purposes of precise definition, a habitat is as elusive as a plant association or a species.

If we can speak of the habitat or environment of a community of plants it must be equally correct to speak of the habitat of even a single individual. Again, seeing that the habitat of a community may continually be undergoing change, it is often difficult to say where the habitat of one phase of a succession ends and that of the succeeding phase begins. It should therefore be possible to speak of the habitat of a succession or sere, at least in cases where, as in a salt marsh, the habitats of successive phases have a common master factor. It would appear then that a habitat may be as narrow as the environment of a single unicellular organism, or as wide as that of a succession of plant associations.

If this be the case, then clearly what we need for practical purposes is not so much a rigid definition of "the habitat"—framed, as such definitions have too often been, to fit particular classes of cases—as a working classification of habitats. So far as I am aware, no satisfactory classification has yet been proposed; indeed the need for a classification at all is only just beginning to be realized. In offering concrete suggestions for your consideration I would point out that at present any attempt to define and classify habitats can only be on broad and general lines. With this proviso, I would suggest that from the point of view of plant ecology:

*A habitat may be described as the place of abode of a plant, a plant community, or in some cases even a* group *or a succession of related plant communities, together with all factors operative u within the abode, bvt external to the* plants *themselves.*

In this working definition I have combined the apparently divergent ideas of various authors as regards the spatial relations of the habitat, as well as the "time and change" ides of Moss and Clements. The idea of "uniformity of conditions" has been discarded, for we have seen that it can apply only in a limited sense and to a limited number of cases. It is therefore out of place in a general definition. Emphasis is laid on the fact that the habitat factors are outside the plant itself. When anything enters the plant from the environment it ceases to form part of the environment.

It is of course impossible to delimit, in a mathematically exact way, the outer spatial boundaries of any habitat, whether of an individual or a community. In many cases too the inner boundaries also are ill-defined, and it becomes difficult to decide precisely where the plant ends and the environment begins'. But such exact delimitation of the habitat is unnecessary; its interest is mainly theoretical. For practical purposes we are concerned with the nature of habitats rather than with their theoretical boundaries.

**A. THOSE PERTAINING TO SYNECOLOGY.**

1. **The Successional Habitat.** *The changing habitat occupied by an allied group of plant associations which, as a rule, comprise the stages of a normal succession or sere.*

The Successional Habitat practically agrees with Clements'.developmental concept of habitat; it corresponds in part to Nichols' "habitat complex."

2. **'The Communal habitat.** *The general habitat of any recognizable plant community, such as an association or a society*

A Communal Habitat usually forms part of a corresponding Successional Habitat, compared with which it is of shorter duration, but relatively more stable. As a rule a communal habitat is occupied by a variety of growth- forms. It more or less corresponds to "the habitat" of most authors.

## B. THOSE PERTAINING TO AUTEGOLOGY.

3. **The Individual Habitat.** *The habitat of an individual plant, whether solitary or forming part of a plant community*

A Communal Habitat is made up of a number of Individual Habitats. These may (a) resemble one another, as when occupied by individuals of the same species, or, if of different species, then of similar growth-form and requirements. Or, (b) differ more or less widely from one another, as will usually be the case when they are occupied by individuals of different growth-form and requirements.

4. **The Partial habitat.** *The habitat of an individual plant during any given period or stage of existence.*

For instance, during a certain stage of development, such as seedling, rosette stage, maturity, etc.; or during a certain season of the year, such as winter, dry season, growing season, and so on. Thus a Partial Habitat is a particular fraction of an Individual Habitat, selected arbitrarily for purposes of research. A group of similar partial habitats may be occupied by individuals of the same species, or by different species of similar growth-form. The partial habitat is not the same thing as the "Lebensort" of Crams.

These four groups could easily be further subdivided, but this had better be left to individual authors in connexion with specific investigations. My aim, in suggesting a broad general grouping of habitats rather than a detailed classification, is to secure recognition of the fact that the term habitat can quite legitimately be used in various ways. In the present state of our knowledge a flexible scheme is probably the most suitable.

*'The same habitat might exhibit retrogressive ae well as progressive changes, e.g. those occurring on a salt marsh. The general habitat of the whole salt marsh would be a aueoessional habitat.*

You will notice that all the four suggested classes of habitats involve *the element of time as* well *as of space*. Hitherto, with the exception of Moss and Clements, the time element appears to have been omitted from the concept of habitat. Thus a successional habitat may endure through a number of stages of a sere; a communal habitat persists through only a single stage, though the lifetimes of many generations may be involved; an individual habitat represents merely the lifetime of a single individual, and a partial habitat only a portion of a single lifetime. Similarly with space. Both the time and space elements are to some extent progressively narrowed in passing from the higher to the lower classes.

Now any habitat, including as it does a complex of variable factors, is a difficult thing to visualize as a whole, and still more difficult to investigate. As regards the larger and more complex habitats the most we can do at present is to investigate in a general way a few of the more prominent factors. If we aim at studying the physiological inter-relations of plant and habitat of which as yet we know very little—we must inevitably narrow our field of enquiry. Seeing that the "partial habitat" is a matter of arbitrary selection, it can be narrowed to any desired extent. For this reason, so far as intensive work in physiological ecology is concerned, it is the study of partial habitats and their occupants which may as a rule be expected to yield results of primary importance. The method of experiment, which is recognized as essential to the solution of so many ecological problems, often means the study of artificially arranged and controlled partial habitats. The essence of all such intensive work is as far as possible to choose and formulate one's problems. It appears to me that Clements, in his stimulating *Research Methods* failed to emphasize this point. He regarded (3, p. l7) "the essential sequence in ecological research" as first the habitat, then the plant, and lastly the plant community. I should exactly reverse this order. It is only after a detailed study of a plant community as such, when one knows the constituent species, their numerical relations, the growth-forms represented, and so on, that one can formulate one's problems. In other words, extensive work should as a rule precede intensive. This is, in point of fact, the actual history of ecology. Up to the present time most ecological work has been of an extensive (synecological) nature; so far as intensive physiological ecology is concerned we are still in the twilight that precedes the dawn.

**Ecological reference herbaria**

In this address I have laid stress on the physiological aspect of the habitat question, because I am a firm believer in the future of intensive ecology. But I fully realize that there may be many members of our Society to whom this side makes no irresistible appeal. At all events they may be so situated that detailed research of this kind is impossible; even primary survey work may not be feasible. To such I should like, in concluding my address, to suggest a scheme for co-operative field work which has long been in my mind. The present occasion seemed to otter a suitable opportunity for ventilating the question. The scheme is, in brief, that our Society should consider the advisability of organizing a central "Ecological Reference Herbarium," or a series of such herbaria, housed in suitable centres. The Secretary has been kind enough to arrange for a separate discussion of this subject, so I need only refer to it now in the briefest terms.

The ordinary herbarium, whether public or private, consists for the most part only of plants in the flowering, or occasionally the fruiting stage. In such a herbarium the ecologist, who is concerned with plants at all stages from seedling to maturity, at all seasons of the year, and with vegetative even more than with reproductive parts, can rarely find answers to his questions. And yet a properly stocked, arranged and annotated herbarium may be for certain purposes as useful as a reference library. At all events the material may be more accessible than that buried in innumerable papers in a hundred and one different journals.

The idea of ecological herbaria is not a new one. Elements (3, p. 196) has suggested what he calls "Formation and Succession Herbaria." But the herbarium I have in mind is a different thing. It would aim not so much at recording the occurrence of species as at accumulating material which might in time be a veritable mine of information useful to ecologists. Such as, for example: developmental stages; growth forms (including root-systems); forms of leaves in different parts of the same plant or at different seasons of the year, and seasonal states generally; habitat forms and so on. The winter conditions of herbaceous plants, a subject ignored by our Floras, but nevertheless of great importance in connection with the study of partial habitats, would no doubt form an important part of any ecological herbarium. In these and other directions comparisons of plants from a variety of habitats would be far more possible were such herbaria available for supplementing—they could of course never replace—individual work in the field.

My idea is that individuals might undertake the detailed study and collection of material at various seasons of the year of, to begin with, one or more species, and pool the results. The scheme would require careful organization in order to avoid unnecessary overlapping. Quality rather than quantity of specimens should be aimed at, and the question of the kinds of information to be collected with the specimens would need careful consideration. The chief difficulty, no doubt a very real one, would be that of organization and supervision; but I do not think that should be beyond the resources of a society such as ours. School teachers could secure the co-operation of senior pupils, and members of field clubs could enlist the sympathies of fellow members. I am confident that it would be useful work, and to me not the least attractive feature of the scheme is that it would afford a common meeting Found for the amateur and the professional botanist. We need unity of purpose rather than uniformity of work, and, as Francis Bacon put it centuries *ago, "*They be two things, unity and uniformity."

NOTE. I regret that a paper by M. Pavillard ("Remarques sur la Nomenclature Phytogéographique." Montpellier, 1919) came to my notice too late to be referred to in this address. On pp. 4—10 he deals with the term *"station"* (= *habitat).* Pavillard suggests that the term *localité* should be used only in a purely geographical sense, and *station* only in an ecological sense. Moreover, he would use *station* primarily as an autecological term, i.e. with reference to the species or individual. "Le *station* (p. 10) c'est]' environnement normal de]'espece, c'est-a-dire une combinaison déterminée de conditions favorables h]'individual vivant (et â sa descendance), mais extérieures h lui."

**Literature cited:**

Adamson, R. S. "An Ecological Study of aCambridgeshire Woodland" *hour*ti. *Lion. d0fi. @Ot.* 40, 1911.

Buckle. P. "A preliminary aurvey of the Soil Fauna of Agricultural Land." *Ann. Appl.* Biol. 8, 1821.

Clements, F. E. *Research* 3fet/rods in Acotop¿f. Lincoln, Nebraska, 1805.

Clements, F. E.' *Prost* diicce.ssion. Carnegie Institution of Washington, 1918. Clments, F. E. *Aeratim and Air-content*. Garnegie Institution of Washington, l9S1. Cocbayne, L. "Observations concerning Evolution, derived from Ecological Studies in

New Zealand." 2'rom.*N.Z. Inst. M,* l8lS.

Cowles 2f. C. "The Ecological Relations of the Vegetation on the Sand Dunea of Lake Michigan." Not. I oz. 27, 1898.

Cutter, D. W. and Cruznp, L. M. "Daily Periodicity in the numbers of active Soil Flagellata: with a brief nots on the relation of Trophic Amosbae and Bacterial numbers." *Ann. Appl. Biol. 4,* 1820.

Du Rietz, G. E. fior *methodolo9iachen 6lrundlaqe der mode* r*tien Pflanzeneoziologie.* Upsala,

Flabault, Ch. and flohriiter, C. *Pkyto9eo9raphical Nomenclature*. Reports and Propo-sitions (3rd International Gongress of Botany), Ziirich, 1910.

r»it«i , r. s. "Problems in Aquatic Biology, with special reference to the study of Algal Periodicity." *New Prnjt. G,* l80fl.

Gazns, H. "Prinzipienfragen der Vegetationaforachung." *Vierteljakrsck. d. Natur,f. Oee. in Ziirick,* 63, 1918.

Ganong, w. r. "The Organization of the Ecological Investigation of the Physiological Life-histories of Plots." Not. Nos. 43, 1907.

Gates, F. C. "Wintsr as a factor in the Xerophily of certain Evergreen Ericads." hot. has. 57, 1914.

Gleason, H. A. "The Vegetation of the Inland Sand Deposits of Illinois." Stdf. Zf/. State

*tab. of Nat.* //T8f. 9, 1910,

Kraus, G. *Boden und Klima auf kieinetem Raum. Ver.*‹ruch einer *exaiten Behan‹lfunq dev lstandorts au,f dem Wellenkalk.* Jena (G. Fischer), 1911.

Massart, J. "Esquisse de la géographie botanique de la Belgique." fiectierf Zmt. hot. fiéo ñrrero, 7 bis, Bruxelles, 1910.

Moss, C. E. "The Fundamental Units of Vegetation." *Neui Phys.* 9, 1810.

Nichols, G. E. "The interpretation and application of certain Terms and Concepts in the ecological classification of plant communities." 7'/re *Plant W* o*rld,* 20, 1917.

Pavillard, J. *L'Aeaociation »égdtaie. Unité phytosocioloqigue.* Montpellier, 1951.

Raunkiaer, C. "Om biologiske Typer, med Hensyn til Plantsrnes Tilpasning til at overleve ugunstige Aarstider." Got. 2'idssU/I, 26, 1904.

Salisbury, E. J. "The Vertical Distribution of Soil Acidity in natural aoils and its relation to the Organic Gonstituente." *'Praz*re. Joroday Society, 19S2. Cf. also thia Jonsxai., 9, Pcb. 1922.

survey, E.a. "Phenology and habitat with special reference to the Phenology of Woodlands." Quart. *Journ*. boy. fled. Joe. 47, 1821.
flchimpor. A. F. W. *Plant-geography vpon a Physiological Baeis*. Oxford, ltl03.
D4iles, W. "An Intensive Study of Habitat Variation." Review of Tirana' "Boden und Klima." This JowenzL, 2, 1914.
Tansley, A. G. *Typee of* brtttsh Fegetntion. Cambridge, 181I.
Tansley, A. G. "The Glaasification of Vegetation and the Concept of Development." This Jonsenc, 8, 1820.
Tyndall, ‹f. *'Phe* Gkiciers o/ tR *Atp.s*. Everyman Edit. London, 1911.
Vostal, A. G. "An associational study of Illinois Sand Prairie." *Bull. Ill. State tab.* o/
*Nat. t8l›* TO, 1913. (not warning, E. *z‹h‹huck der Okoloqiechen P flat::enqeo9raphie*. Berlin (Borntraeger), 1896.
Warming, E. Scok›gy o/ #fonh. Oxford, 1909.
Weaver, J. E. *'The Illcolaqical Relations* o/ look. Garnegie Institution of Washington, 1919.
Woodhead, T. W. "Ecology of Woodland Plants in the neighbourhood of ITudderafield."
*Journ. Finn. Soc. Bot. Z'7,* 1908.
Yapp, R. If. " On stratification in the Vegetation of a Marsh, and ite Relations to Evaporation and Temperature." *Are. Bot*. 23, 1909.
Yapp, R. H. *"Spiraea Ulmaria* L., and its Bearing on the Problem of Xeromorphy in Marsh Planta." *Ann. Bot*. 26, 1912

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# 4 Data Collection Methods

**OBJECTIVES**
On going through this Unit you will be able to:

- Explain the concept and types of data;
- Identify the importance of data in a statistical inquiry,
- Explain various survey techniques; and
- Identify the uses and limitations of secondary data.

**INTRODUCTION**

We face problems in various fields of our life, which force us to think and discover their solutions. When we are genuinely serious about the solution of a problem faced, a thinking process starts. Statistical Thinking or Statistical Inquiry is one kind of thinking process which requires evidence in the form of some information, preferably quantitative, which is known as data/statistical information.

In a statistical *inquiry,* the first step is to procure or collect data. Every time the investigator may not start from the very beginning. He must try to use what others have already discovered. This will save us in cost, efforts and time.

As discussed in Unit 1 (Section 1.2.1) data imply related quantitative information. They are collections of any number of related observations with a predetermined goal. We can collect information on the number of T.V. sets sold by a particular salesman or a group of salesmen, on weekdays in different parts of Delhi to study the pattern of sales, lean days, and effect of competitive products, income behavior and other related matters. The information thus collected is called a data set and' a single observation a data point.

All types of information collected without proper aim or objective is of no use. For example, John's height is 5'6" or monthly wage of Mr. X on 1ST January 2004 were Rs. 15000/- are not data. Not all quantitative information are statistical. Isolated measurements are not statistical data. Statistics (that is in singular sense) is concerned with collection of data relevant to the solution of a particular problem. According to Simpson and Kafka (Basic Statistics),"Data have no standing in themselves; they have n basis for existence only where there is a problem".

**PURPOSE OF DATA COLLECTION**

By now you have known that data could be classified in the following three ways:

a) Quantitative' and Qualitative Data.

b) Sample and Census Data.

c) Primary and Secondary data.

a) Quantitative and Qualitative data: Quantitative data are those set of information which are quantifiable and can be expressed in some standard units like rupees, kilograms, litres, etc. For example, pocket money of students of a class and income of their parents can be expressed in so many rupees; production or import of wheat can be expressed in so many kilograms or lakh quintals; consumption of petrol and diesel in India as so many lakh litres in one year and so on.

Qualitative data, on the other hand, are not quantifiable, that is, cannot be expressed in standard units of measurement like rupees, kilograms, liters, etc. This is because they are 'features', 'qualities' or 'characteristics' like eye-colours, skin complexion, honesty, good or bad, etc. These are also referred to as attributes. In this case, however, it is possible to count the number of individuals (or items) possessing a particular attribute.

b) Sample and Census Data: It was discussed in Section 1.2.3 of Unit 1 that data can be collected either by census method or sample method. Information collected through sample inquiry is called sample data and the one collected through census inquiry is called census data. Population census data are collected every ten years in India.

c) Primary and Secondary Data: As discussed very briefly in Section 1.2.2, primary data are collected by the investigator through field survey. Such data are in raw form **and** must be refined before use. **On** the other hand, secondary data are extracted from the existing published or unpublished sources, that is, from the data already collected by others.

Collection of data is the first basic step towards the statistical analysis of any problem. The collected data are suitably transformed and analysed to draw conclusions about the population. These conclusions may be either or both of the following:

*i)* To estimate one or more parameters of a population or the nature of the population itself. This forms the subject matter of the theory of estimation (discussed in Block 7).

*ii)* To test a hypothesis. A hypothesis is a statement regarding the parameters or the nature of population (discussed in Block 7).

## COLLECTION OF DATA

Collection of reliable and sufficient data\statistical information is a pre-requisite of any statistical inquiry. This and the subsequent Sections of this Unit are devoted to data collection techniques.

### Statistical Inquiry - Planning and Conduct

Collection of reliable and sufficient data requires a careful planning and execution of a statistical survey. If this is not so then the result obtained may be misleading or incomplete and hence useless. They may even do more harm than good. In the following Section an attempt is made to explain planning aspect.

Statistical data can be collected either by a survey or by performing an experiment. Surveys are more popular in social sciences like economics and business. In natural\ physical sciences experimentation is more commonly used method of investigation.

Data collected by observing various individuals or items, included in a survey, are affected by a large number of uncontrollable factors. For example, wages in a country are affected by a lot of factors like skill, education and sex of worker; training and experience; and in some countries even on race to which a worker belongs. In India low caste and historically underprivileged people like sweepers are the least paid workers for social reasons also.

It is interesting to note that even the data obtained through experiments in physical sciences are affected by a large number of uncontrollable factors in spite of the fact that such experiments are conducted under controlled conditions. The uncontrollable factors, in this case, may arise due to the bias of the person(s) conducting the experiment, nature and accuracy of measuring instrument, etc.

Any statistical survey consists of two stages:

**i)** Planning Stage
**ii)** Executing Stage

### Planning Stage - Requisites of a Statistical Inquiry

Before collecting data through primary or secondary source, the investigator has to complete the following preliminaries.

***a) What is the objective / aim and scope of the inquiry?***

Unless the investigator answers this question most satisfactorily, (s)he cannot proceed in the right direction and can go astray. Both money and efforts will be lost if data, not relevant to inquiry, are collected. Not only this, one must also be clear about how much data are required and hence ensure that only the necessary data get collected. For example, if we want to collect data on pattern of wheat production in a particular state, we need to collect data on the type of land, agricultural inputs, educational levels of farmers involved, presence or absence of defects of land tenure system, availability and cost of agricultural finance, **nature** of marketing, etc.

***b) What shall be the source of information?***

The investigator **has** to make a choice between primary source, where he himself collects the **data,** or secondary source, where he lays his hand on already collected data.

**c) What shall be the nature of question?**

That is, the investigator has to make a choice between:

1) *Census* or *Sample* inquiry. In census method (s)he examines each and every item / individual of the population whereas in sample method (s)he examines only the item *1* individual included in the sample. For example, in *census* method (s)he examines each and every persons in a village, but in sample method, (s)he examines only a limited number of persons.

2) *Direct* or *Indirect* inquiry. In a direct inquiry the observations can be directly obtained in quantitative terms as for example, sales of T.V. sets and the advertisement cost in rupees. On the other hand, in an indirect inquiry, like intelligence of a group of students, marks secured by them are used to judge their intelligence.

3) *Original* or *Repetitive* inquiry. *An* inquiry conducted for the first time is original but if it is undertaken over and over again, it is repetitive. For example, population census in India is conducted every 10 years. *All* these inquiries must be related.

4) *Open* or *Confidential* inquiry. In open inquiry the results are made public, as for example, the population and national income data. On the other hand, the results of many government inquiries are kept confidential for reasons of national security, as for example, data on defence, atomic energy, space research and development, etc.

***d) What shall be the statistical units of investigation or counting?***

A statistical unit is an attribute or a set of attributes conventionally chosen so that individuals or objects possessing them may be counted or measured for the purpose of enquiry. Thus a statistical unit is ***a*** characteristic or a set of characteristics of an individual or item that are observed to collect information. For example, various characteristics of a person may be his height, weight, income, etc. The definition of a statistical unit means the specification of the characteristics of an individual or item on which data are to be collected.

It must be pointed out that the result of observation of a statistical unit may be a number which is obtained-either by counting or by measurement. If the number is obtained by measurement, it is also necessary to specify the units of measurement. The specification of statistical units and the units of measurements is very necessary for the maintenance of uniformity in the collected data.

***e) What shall be the degree of accuracy?***

In various economic and business studies, absolute accuracy is neither necessary nor possible. In population data, accuracy till the last person is not required. For example, population of India is 98, 89,70,510 or 98 ,89,00,000 does not matter much. However, the degree of accuracy required will determine the choice between different methods of collecting data. Further, the degree of accuracy, once decided, must be maintained throughout the survey.

**Execution Stage**

This stage comes after the planning stage, where the plan is put in operation. It includes:

1) Setting up the *central administrative machinery* which prepares a format of questions relating to the inquiry, called a *questionnaire* or a *question schedule*. It decides the setting up of branch offices to cover large geographical area.

2) *Selection* and *Training* of field staff called interviewers or investigators or research staff or enumerators. They will approach the respondents in different ways as explained in Section 2.4. Investigators should be properly trained, should be honest and hardworking. Any error at this stage will jeopardize the whole process of investigation giving misleading results. To obtain the best possible results h m a survey, it is desirable to have the field staff who is familiar with the language of the respondents and have patience and tact of dealing with them.

3) *Supervision* of field *staff* is a must to ensure that information is actually obtained from the respondents rather than that the questionnaires are fictitiously filled up in hotel rooms. Further, there must be some experts to make clarification3 on problems faced by the investigators in the field work.

While conducting field surveys the problem of *non--response is* common.

This includes:

a) Non-availability of the listed respondent. Here in no case this respondent be replaced by another because it may spoil the random character of sample and the results of investigation are likely to become biased.

b) Due to non-response, a part or certain questions of the questionnaire may remain unanswered or partly answered. These should not be replaced or tempered with by the investigator.

4) After the data have been arranged, the next job is to analyse the same. The methods of doing this are fully described in later Blocks. Now-a-days computers are available to do this job.

5) After analysis of data, now is the turn for writing a detailed report mentioning the main findings of the survey\statistical inquiry. The main conclusions drawn and policy recommendations are duly recorded at the end of this report.

**Primary and Secondary Data**

A pertinent question that arises now is how and from where to get data? Data are obtained through two types of investigations, namely,

**1)** ***Direct Investigation*** which implies that the investigator collects information by observing the items of the problem under investigation. As explained above, it is the primary source of getting data or the source of getting primary data, and can be done through observation or through inquiry. In the former we watch an event happening, as for example, number and type of vehicles passing through Vijay Chowk in New Delhi during different hours of the day and night. In the latter we ask questions from the respondents through questionnaire (personally or through mail). It is a costly method in terms of money, time and efforts.

**2)** ***Investigation through Secondary Source*** which means obtaining data from the already collected data. Secondary data are the other people's statistics, where other people includes governments at all levels, international bodies or institutions like IMF, IBRD, etc., or other countries, private and government research organisations, Reserve Bank of India and other banks, research scholars of repute, etc. Broadly speaking we can divide the sources of secondary data into two categories: published sources and unpublished sources.

### A) Published Sources

1) Official publications of the government at all levels - Central, State, Union, Territories and Councils.

2) Official publications of foreign countries.

3) Official publications of international bodies like IMF, UNESCO, WHO, etc.

4) Newspaper and Journals of repute, both local and international.

5) Official publications of RBI, and other Banks, LIC, Trade Unions, Stock Exchange, Chambers of Commerce, etc.

6) Reports submitted by reputed economists, research scholars, universities, commissions of inquiry, if made public.

**Some main sources of published data in India are:**

i) **Central Statistical Organisation (C.S.O.):** It publishes data on national income, savings, capital formation, etc. in a publication called National Accounts Statistics.

ii) **National Sample Survey Organisation (N.S.S.O.):** Under Ministry of Statistics and Programme Implementation, this organisation provides us data on all aspects of national economy, such as agriculture, industry, labour and consumption expenditure.

iii) **Reserve Bank of India Publications (R.B.I.):** It publishes financial statistics. Its publications are Report on Currency and Finance, Reserve Bank of India Bulletin, Statistical Tables Relating to Banks in India, etc.

iv) **Labour Bureau:** Its publications are Indian Labour Statistics, Indian Labour Year Book, Indian Labour Journal, etc.

v) **Population Census:** Undertaken by the office of the Registrar General India, Ministry of Home Affairs. It provides us different types of statistics about population.

### B) Un-published Sources

1) Unpublished findings of certain inquiry committees.
2) Research workers' findings.
3) Unpublished material found with Trade Associations, Labour Organisations and Chambers of Commerce.

**COLLECTION OF PRIMARY DATA - SURVEY TECHNIOUES**

After the investigator is convinced that the gain from primary data outweighs the money cost, effort and time, she\he can go in for this. She\he can use any of the following methods to collect primary data:

a) Direct Personal Investigation
b) Indirect Oral Investigation
c) Use of Local Reports
d) Questionnaire Method

### a) Direct Personal Investigation

Here the investigator collects information personally from the respondents. She/he meets them personally to collect information. This method requires much from the investigator such as:

1) She/he should be polite, unbiased and tactful.
2) She/he should know the local conditions, customs and traditions so that she/he
3) She/he should be intelligent possessing good observation power.
4) She/he should use simple, easy and meaningful questions to extract information.

This method is suitable only for intensive investigations. It is a costly method in terms of money, effort and time. Further, the personal bias of the investigator cannot be ruled out and it can do a lot of harm to the investigation. The method is a complete flop if the investigator does not possess the above mentioned qualities.

### b) Indirect Oral Investigation Method

This method is generally used when the respondents are reluctant to part with the information due to various reasons. Here, the information is collected from a witness or from a third party who are directly or indirectly related to the problem and possess sufficient knowledge. The person(s) who is/are selected as informants must possess the following qualities:

1) They should possess full knowledge about the issue.
2) They must be willing to reveal it faithfully and honestly.
3) They should not be biased and prejudiced.
4) They must be capable of expressing themselves to the true spirit of the inquiry

### c) Use of Local Reports

This method involves the use of local newspaper, magazines and journals by the investigators. The information is collected by local press correspondents and not by the investigators. Needless to say, this method does not yield sufficient and reliable data. The method is less costly but should not be adopted where high degree of accuracy or precision is required.

### d) Questionnaire Method

It is the most important and systematic method of collecting primary data, especially when the inquiry is quite extensive. It involves preparation of a list of questions relevant to the inquiry and presenting them in the form of a booklet, often called a questionnaire. The questionnaire is divided into two parts:

1) General introductory part which contains questions regarding the identity of the respondent and contains information such as name, address, telephone number, qualification, profession, etc.

2) Main question part containing questions connected with the inquiry. These questions differ from inquiry to inquiry.

Preparation of the questionnaire is a highly specialized job and is perfected with experience. Therefore, some experienced persons should be associated with it. The following few important points should be kept in mind while drafting a questionnaire:

i) The task of soliciting information from people in desired form and with sufficient accuracy is the most difficult problem. By their nature people are not willing to reveal any information because of certain fears. Many a times they provide incomplete and faulty information. Therefore, it is necessary that the respondents be taken into confidence. They should be assured that their individual information will be kept confidential and no part of it will be revealed to tax and other government investigative agencies. This is very essential indeed.

ii) Always avoid personal questions which may embarrass the respondents. For example, questions like 'Do you evade income tax?' or 'Are you engaged in smuggling or black marketing?' should not be asked.

iii) Questions hurting the sentiments of respondent should not be asked. These include questions on his gambling habits, sex habits, indebtedness, etc.

a) Questions involving lengthy and complex calculations should be avoided because they require tedious extra work in which the respondent may lack both interest as well as capabilities. In such cases it would be better to

b) either get documents like balance sheet, profit and loss account and inventory record from the respondent from where we can get or calculate the required information himself, or

c) Ask indirect and simple questions which, with some calculation later on, can help us to acquire the required information.

iv) Ask questions which enable to cross check the correctness of the information supplied by the respondent. For example, questions on total wage bill of a factory can be cross checked if the other questions seek information on different types of workers working in administrative, production, store and marketing departments. Similarly information on saving of a household can be cross checked by getting information on different sources of income and its expenditure on different heads.

v) As far as possible questions should be of Yes/No type. These are precise and simple to understand, and take very little time to answer. Later on they are easy to tabulate. For example,

Are you married? Yes/No

Tick the right answer.

vi) Questions should be short and clear. That is, they should not be ambiguous and confusing. As far as possible, attempt should be made to suggest the possible answers to a question and the respondent may be asked to simply tick the answer/s he/she thinks is/are correct.

Since the list of answers may not be exhaustive, therefore, a line of "others, if any" should also be inserted leaving sufficient blank space for the answer.

Following is an example of a question:

Why do people not exercise their right to vote? Tick the right answer:

a) They are illiterate and do not understand the value of the vote.

b) They think, it does not matter if their one vote is not cast out of lakhs

c) The polling booths are far from their residence. \

d) They are afraid of the local goons and violence.

e) They are not happy with the government and do not vote out of protest.

f) They do not vote unless some money is offered to them.

g) Any other reason, please state.

This form of questions and answers also helps in arranging and tabulating the data.

vii) A very large number of questions should be avoided because it leads to the feeling of monotony. Many respondents will hesitate to answer a long list of questions, for want of time and interest.

**A sample questionnaire on family planning is reproduced below.**

Survey on Family Planning

1. Name ...........................................................................................
2. Father's / Husband's Name ......................................................
3. Residential address.................................... ............................
4. Place of Work ............................................................. ...........
5. Age ................................ 6. Male/Female............................
7. Religion .......................... 8. Telephone No. ...........................
9. Profession:
a) Self.......................... b) Spouse..........................
10. Annual Income of the family from all sources ...........................
11. Educational Qualifications: (Tick () the right answer)
a) Illiterate b) Primary standard
c) Middle standard d) Secondary
e) Sr. Secondary f) Graduate g) Post graduate
12. Educational Qualifications of spouse: (Tick () the right answer)
a) illiterate b) Primary standard
c) Middle standard d) Secondary
e) Sr. Secondary f) Graduate g) Post graduate
13. Number of years of marriedlife................................................
14. Number of children born: Girls.................... Boys ..................
15. Number of surviving children: Girls .................Boys ..............
16. State the gap in years between the children
a) Between marriage and first child: .........................................
b) Between first and second child: .........................................
c) Between second and third child: .........................................
d) Between third and fourth child: .........................................
e) Between fourth and fifth child: .........................................
f) Between fifth and sixth child..........................................
1 7. Do you favour family planning? (Yes/No)
18. If no, what are the reasons?
a) Children are natural gift: (Yes/No)
b) Family planning is against my religion: (Yes/No)
c) Family planning means murdering an unborn child:(Yes/No)
d) Number of children is the part of my fate: (Yes/No)
e) Any other reason, please state: .............................................
19. If you favour family planning, state the reasons
a) Small family is a happy family: (Yes/No)
b) Two children can be controlled easily: (Yes/No)
c) Two children can be properly educated and fed: (Yes/no)
d) There are fewer complications in life:(Yes/No)
e) The health of the mother is not adversely affected: (Yes/No)
f) Any other reason, please state:

20. State Age, Educational Level and Health Condition of your children.

| Sr.No | Name | Age | Educational Level | Health condition* |
|---|---|---|---|---|
| 1) | ................ | ......... | ........................... | ........................... |
| 2) | ................ | ......... | ........................... | ........................... |
| 3) | ................ | ......... | ........................... | ........................... |
| 4) | ................ | ......... | ........................... | ........................... |

(*State whether Poor, Below Normal or Excellent)

**How to approach the Respondent with a Questionnaire?**

There are three methods available to us:

i) Send the questionnaires by post to the respondents with a forwarding letter highlighting the importance of the survey to them as well as to the community or nation, and requesting cooperation in filling it and then you can sit back and wait for the response. It is often seen that the response is generally poor.

ii) Send the questionnaire through investigators, who will interview the respondents and record the information personally. This method, though costly, is better. It helps the respondents to understand questions properly. The response is certainly better because the scope of laziness and irresponsibility is reduced. A clever and intelligent investigator with tact and initiative is able to get better response.

iii) Send the questionnaire by post followed by the visit of the investigator. This in fact is the best method as it combines the benefits of both the methods. It, no doubt, is a costly method. It is very useful for extensive studies. Being expensive, it can and is normally used by Government who has financial resources at its command.

**COLLECTION OF SECONDARY DATA**

As pointed out in Section 2.3.4 that direct investigation, though desirable, is costly in terms of money, time and efforts. Alternatively, infomation can also be obtained through a secondary source. It means drawing or collecting data from the already collected data of some other agency, Technically, the data so collected are called secondary data.

**Limitations of Secondary Data**

Although the secondary source is cheap in term of money, time and effort, utmost care should be taken in their use. It is desirable that such data should be vast and reliable- and the terms and definitions mutt match the terms and definitions of the current inquiry. The suitability of the data may be judged by comparing the nature and scope of the present inquiry with that of original inquiry. Secondary data will be reliable if these were collected by unbiased, intelligent and trained investigators. The time period to which these data belong, should also be properly scrutinized. Comer has rightly remarked, "Statistics, especially other people b statistics are full ofpitfalls for the user". Needless to say, before using secondary data, the investigator must weigh the advantage in terms of saving of money, time and effort with the disadvantage of reaching misleading conclusions. Whether secondary data are safe or not should be judged from its adequacy, suitability and reliability.

Thus, before the use of secondary data, i.e., otherpersons' data, we must properly scrutinize and edit them to find whether these data are:

1) Reliable,
2) Suitable, and
3) Adequate.

Reliability of data has to be the obvious requirement of any data, and more so of secondary data. The user must make himself/herself sure about it. For this(s) he must check whether data were collected by reliable, trained and unbiased investigators from dependable sources or not. Second, we should see whether data belong to almost the same type of class of people or not. Third, he should make sure that due to the lapse of time, the conditions prevailing then are not much different from the conditions of today in respect of habits, customs, fashion, etc. Of course we cannot hope to get exactly the same conditions.

Suitability of data is another requirement. The research worker must ensure that the secondary data he plans to use suits his inquiry. He must match class of people, geographical area, definitions of concepts, unit of measurement, time and other such parameters of the source he wants to use with those of his inquiry. Not only this, the aim and objectives should also be matched for suitability.

Secondary data should not only be reliable and suitable, but also adequate for the present inquiry. It is always desirable that the available data be much more than required by the inquiry. For example, data on, say, consumption pattern of a state cannot be derived from the data on its major cities and towns.

**LET US SUM UP**

Data / Statistics are quantitative information and can be distinguished as sample or census data; primary or secondary data.

For conducting an inquiry, we need data which can be collected afresh or from a secondary source. Both require statistical survey which has a planning stage and an executing stage. In the planning stage, the investigator should decide whether to use primary or secondary source, census or sample inquiry, nature of the statistical units and the units of measurement, degree of accuracy desired and so on.

In the execution stage, the chief investigator has to set up administration, select and train field staff and supervise the entire process of data collection.

Care has to be taken in using the secondary data, derived from published or unpublished source, as they contain various pitfalls.

Of all the survey techniques, the questionnaire method is very important. A questionnaire contains a set of relevant questions which should be simple, unambiguous, YedNo type with suggestive answers. Their list should not be very long. Personal and embarrassing questions should be avoided.

**KEY WORDS**

**Data Point:** It is an observation from an individual or item.

**Data Set:** It is the collection of a11 data points.

**Census Data:** The data obtained by observing all the items of population.

**Sample Data:** The data obtained by observing only those items which are included in the sample.

**Primary Data:** Data obtained by observing the items or individuals under the ambit of a problem under consideration.

**Secondary Data:** Data obtained from the already collected data of some agency.

**Questionnaire or Schedule:** It is a list of questions that are relevant to the inquiry at hand.

**Statistical Inquiry:** An inquiry that requires information in the form of figures for its investigation.

**Statistical Survey:** It is a method for the collection of data by observing all or a sample of items under the ambit of a given problem.

**Statistical Unit:** It is a characteristic or a set of characteristics of an item that are observed to collect data.

**Respondent:** The person who supplies the information.
**Investigator:** The person responsible for the collection of information from respondents.
**Hypothesis:** It is an assertion or statement about a population.
**Test of Hypothesis:** Testing the validity of a hypothesis on the basis of collected data.

**SOME USEFUL BOOKS**

Elhance, D. N. and V. Elhance, 1988, Fundamentals of Statistics, %tab Mahal, Allahabad.
Nagar, A. L. and R. K. Dass, 1983, Basic Statistics, Oxford University Press, Delhi.
Mansfiedl, E., 1991, Statistics for Business and Economics: Methods and Applications, W.W. Norton and Co.
Yule, G. U. and M. G. Kendall, 1991, *An* Introduction to the Theory of Statistics, Universal Books, Delhi.

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# 5 Avian surveys and monitoring

A more complete understanding of the role that wild birds play in the ecology of wildlife diseases require baseline studies of those species likely to host, transmit or spread patho- gens. Baseline studies of wild bird populations will generally fall into three categories: inventory and monitoring, movement patterns and behavioural studies. Initial studies will likely focus on inventory and monitoring with specific objectives that include: 1) an inven- tory of all the bird species in an area of interest; 2) determining the abundance or density of the species present; and 3) monitoring seasonal changes in species composition and numbers. When applied to understanding the emergence of infectious diseases such as H5N1 AI, these techniques serve to provide an early warning system for detection of higher than expected mortality rates in wild bird populations.

Species inventories and population monitoring are common tasks of biologists, and a variety of avian survey and monitoring techniques are available. While each technique has its advantages, the most appropriate technique will depend on the specific objectives of the study, the size of the study area, characteristics of the species and habitat of interest, and the logistic and financial feasibility of implementing the study. This Manual provides a brief review of some the practical techniques used to survey and monitor avian populations, with special emphasis on those techniques applicable to waterbirds, shorebirds and other species known or suspected of hosting, transmitting or spreading the H5N1 virus.

Various approaches can be employed to assess wild bird species composition and abun- dance over an area of interest, from total counts of all animals present (a complete census) to sampling strategies that provide population estimates that can be extrapolated over the entire study area. One important precept applies regardless of the technique employed: it is essential that all techniques are properly described and surveys are conducted by qualified personnel using standard methods that are consistent over time. Observers will undoubt- edly encounter a variety of species, conditions and habitats during surveys, but counts are of little use if the species identification is dubious and the survey methodology varies from one day to the next or among sites. Thus, observers should be able to identify most, if not all, of the species likely to be encountered during a survey, including closely-related species that may be nearly identical, and different sexes and age groups within a species.

## Complete censuses

The goal of a complete census is to conduct a total count of all the animals present over a specified area to obtain an unbiased estimate of abundance without statistical inferences or underlying assumptions. A reliable census is conditional on the assumption that all individu- als present in an area can be recorded; therefore, censuses are most useful for conspicuous species occupying discrete and well-defined habitats. Some situations in which a reliable census may be possible include complete counts of herons and cormorants nesting in trees along a wetland margin, water birds frequenting small open wetlands, or shorebirds at high tide roost sites in estuaries.

FIGURE 5.1
**Bird survey with a telescope**

CREDIT: TAEJ MUNDKUR

However, in many situations, such as where waterbirds are very numerous or tightly grouped or where time is limited, it may be necessary to estimate the number of individuals rather than to count every individual. Experienced counters can accurately estimate 10, 20, 50, 100 or more birds almost instantaneously, and scan through flocks counting in these units with a tally counter. It is preferable to estimate in small units (10 is probably the most commonly used unit); units of 100 or more are generally used for birds in flight or on nests (for colonial nesting species), and when time is limited.

A complete census is more practical when targeted at large and conspicuous species such as swans or geese and is the preferred method especially where there are active networks of participants to undertake the work. This kind of approach is promoted for periodic special census of swans by organisations such as Wetlands International/IUCN/SSC Swan Specialist Group at the regional level (*see for* e.g. Worden *et al.* 2006). For large-scale coordinated census of waterbirds, such as under the annual International Waterbird Census coordinated by Wetlands International (Delany 2005a, 2005b), all the birds of a selection of appropriate species, at a selection of suitable sites are covered, in a series of "look-see surveys" (*sensu* Bibby *et al.* 1998).

Achieving the ambitious goals of a conventional census count will often involve consid- erable logistic preparations. A large census area will usually need to be divided into smaller units that can be conveniently surveyed over time or by multiple field personnel at the same time. In the latter case, the survey team requires proper training in census techniques, species identification, accurate number counting or estimation, and use of field equipment (e.g. spotting scopes, Global Positioning System - GPS). In either case, the survey period should also be considered. Observers need enough time to thoroughly examine each survey unit, but not so much time that individuals of the target species move between survey units and are counted more than once.

The census area also needs to be accurately mapped and the entire area completely surveyed. Individual survey units should be easily discernable in the field because poorly defined unit boundaries may result in missing or double counting individuals. All habitats in the survey area which are suitable to the target species must be searched. Incomplete coverage (e.g. neglecting areas considered less suitable to the target species) may miss some individuals and introduce biases in the survey data.

Photographic or video images provide an efficient census technique that has been used increasingly in recent years. This involves producing a set of photograph or video images covering the entire area of interest (and all the animals within) which can be counted at a later time. Photographic and video surveys are usually conducted from aircraft, but any platform which provides unobstructed views of the survey area is suitable for conducting a census.

Photographic surveys must be conducted at a distance (or altitude) that produces images with sufficient resolution to permit species identification and distinguish individual birds in sometimes dense flocks or colonies, but not so close that the spatial relationship among images is lost. Concurrent ground- or boat-based surveys are advisable when con- ducting aerial photographic or video surveys to verify species identification and examine other potential biases.

**Sample plots**

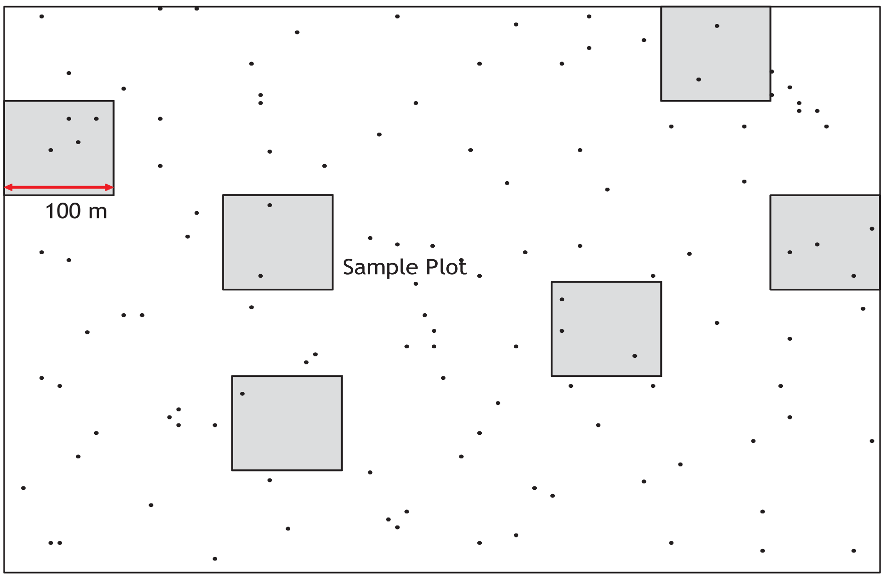
In many studies, the time and effort required to conduct a complete and accurate census is prohibitive, usually because the area of interest is too large to adequately survey in a reasonable amount of time. In such cases, sample plots can provide data indicating species diversity and the abundance of each species within the study area. Sample plots are most amenable to ground-based observers because time is less of a limiting factor than in boat- based or aerial surveys, allowing for greater search effort dedicated to ensuring accurate counts and proper species identification.

Sample plots need not be limited to counts of actual birds and cannot be used for that purpose where birds move between sample plots during counts. Sample plots are most use- ful when the target species (or objects) are relatively immobile over the survey period, for example wading birds attending discrete roost sites. Specific applications of sample plots to AI-related wildlife investigations may include estimating waterbird nest densities or the number of carcasses at an H5N1 outbreak site.

The selection of sample plots should be carefully considered when designing a study because plot location can have a strong influence on population estimates. Considera- tion must be given to factors such as bird behaviour and heterogeneous habitats which may result in non-random animal distributions that require stratified sampling techniques. Details of more sophisticated sample plot design and analysis techniques are beyond the scope of this Manual, but Bibby *et al.* (1998, 2000) provide useful references[9].

FIGURE 5.2

**Use of sample plots for estimating avian density & abundance**



In the simplest applications, complete counts of all animals *(n)* in sample plots of known size *(a)* are conducted and the plot density is calculated as $d = n / a$. The average density *(D)* from all the plots can be calculated and extrapolated over the entire study area *(A)* to pro- vide an estimate of total animal abundance *(N = D / A)*, although more sophisticated means of determining average density by examining variability in sample plots may be desirable.

Figure 5.2 illustrates a simplified example of the use of sample plots to determine water- bird nest density and abundance.

Actual density in this hypothetical population of 120 nests distributed over 0.48 $km^2$ is 250 nests $km^{-2}$. A total of 16 nests are detected in the six randomly chosen 100 $m^2$ plots for an average density of 267 nests $km^{-2}$ (16 nests / 0.06 $km^2$) and an abundance estimate of 128 nests (267 nests $km^{-2}$ x 0.48 $km^2$) over the entire study area.

The accuracy of density estimates will increase as survey effort (the number or size of the plots) increases. In the above example, sampling a single 100 $m^2$ plot could result in densities ranging from 0 to 800 nests $km^{-2}$. The size and number of sample plots will depend on the effort required to detect individuals of the target species. Intuitively, more or larger plots can be established for species that are easier to detect and require less search time per individual, thus moving closer to the conditions of a complete census.

Sample plots need not be square (quadrats), although regularly shaped plots (e.g. square or circular) are usually easier to demarcate and search. If plots are to be repeatedly surveyed, boundaries should be marked and coordinates recorded with a GPS unit.

**Strip transects**

Strip transects are one of the most commonly used survey techniques for determining avian species composition and density. Essentially, strip transects are modified versions of a sample plot in which the observer performs counts while traveling along a fixed transect line instead of searching over an entire plot.

Transects are randomly located, often within stratified sub-areas of the total study area, to obtain representative samples of the species and numbers of each species present. If density estimates are desired, the counts are limited to objects within a fixed distance of the transect line. In such cases, the sampled plot becomes a rectangular strip extending a specified distance on either side of the transect line.

Strip transects have been adapted for a variety of species and habitats that have direct applications to AI-related studies. Aerial and boat-based strip transect methodologies have been specifically developed for conspicuous aquatic species and these techniques have become the preferred survey method in large open water habitats. Aerial strip transects can be established to assess the distribution and abundance of waterfowl over broad geo- graphic areas where waterfowl habitat overlaps with poultry production, agricultural fields and other potential H5N1 outbreak zones. Over smaller scales, ground-based strip transects established along the interface between waterbird habitats and poultry operations can identify particular species likely to bridge these habitats.

As for sample plots, the density from a strip transect plot can be extrapolated over the study area to obtain an abundance estimate. Figure 5.3 illustrates a simplified example of a 50 m strip transect (extending 50 m on each side of the line).

As in the previous example, actual density is 250 animals $km^{-2}$. A total of 17 animals are detected within the 700 m long by 100 m wide transect for a density of 243 animals $km^{-2}$ (17 animals / 0.07 $km^2$) and an abundance estimate of 117 animals (243 animals $km^{-2}$ x 0.48 $km^2$) over the entire study area.

In practice, strip transect methodology is rarely as simple as the above example sug- gests, and several factors must be considered before surveys can be conducted. If density estimates are desirable, choice of the appropriate strip transect width is a compromise between maximising detection probability for the target species and surveying as large an area as possible. Intuitively, detection probability (and strip transect width) increases for large, conspicuous species in more open habitats. Obviously, it is senseless to establish a 400 m wide strip transect to count tiny sandpipers foraging in a vegetated wetland, just as it is inefficient to use a 50 m strip transect to survey large and conspicuous swans on a lake.

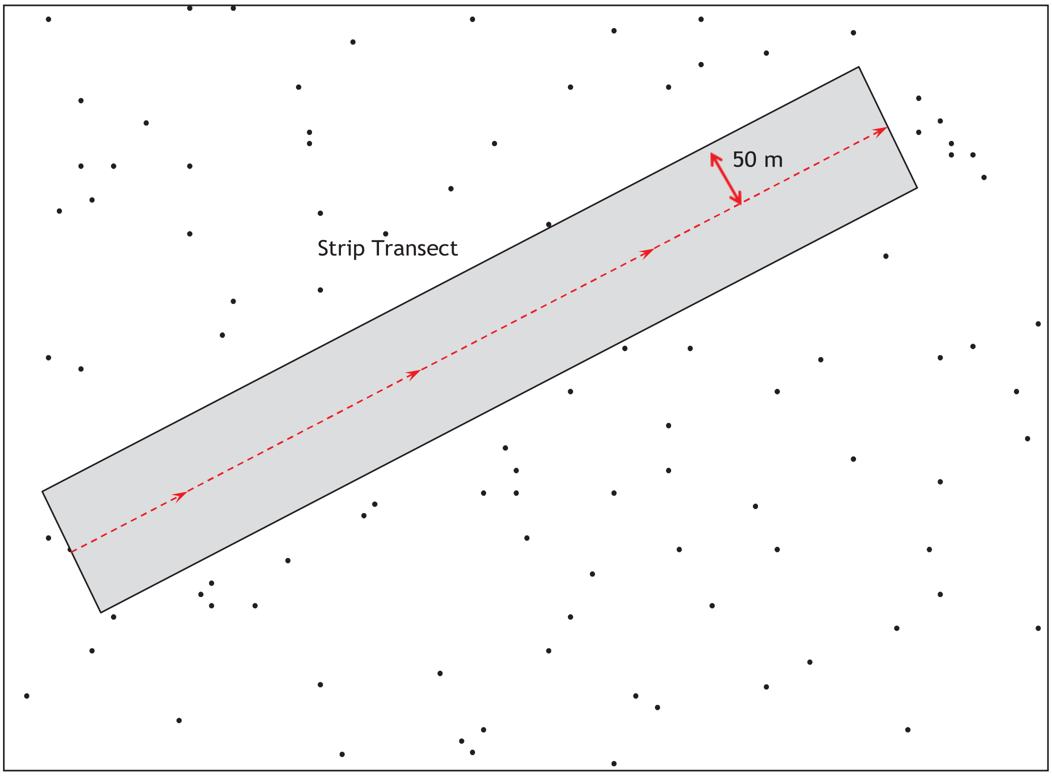
Like sample plots, density estimates from strip transect surveys operate on the assump- tion that all animals within the plot are detected, thus surveys are best conducted in open habitats where visibility is unobstructed. However, unlike sample plots, the observer does not usually leave the transect line to search the plot, thus complete detection of all animals in the plot may be difficult to achieve. Binoculars (image-stabilised models are best) are commonly used during ground- and boat-based strip transect surveys to aid visual detec- tion and species identification, but visual aids are of little use during aerial surveys.

The ability to make quick and accurate assessments of bird locations in relation to survey boundaries is imperative for reliable density estimates. Errors in estimating bird location relative to the transect line can have a considerable effect on density estimates. In the illustrated example (Figure 5.2), counting three individuals located just outside the bound- ary results in a density of 287 animals $km^{-2}$, while excluding three just inside the boundary yields 200 animals $km^{-2}$.

Consistent assessments of bird location in relation to the boundary require that aerial surveys be conducted at the same altitude and boat-based observers are stationed at similar heights above the water (and these parameters are accurately recorded). Aids to distance estimation, such as range finders or markings on airplane windows or wing struts, are helpful for calibrating the observer's eye during the training period, but reliance on these aids often distracts from the primary task of identifying and counting birds.

Strip transects can be conducted by observers on the ground, in boats or in aircraft. Aerial surveys offer far greater spatial coverage (and incur much higher costs) compared to ground- and boat-based surveys, although the extended range sometimes comes at the expense of accuracy, as the speed of the aircraft limits observation time and may make accurate counts and species identification more challenging. In fact, performing a good aerial survey requires specific training and experience.

FIGURE 5.3
**Use of strip transects for estimating avian density and abundance**




*Note:* Dots represent individual birds.

If biases among survey platforms are suspected, concurrent counts using different survey methods are advisable (triangulation of the data and information). For example, observers on aerial surveys may be more likely to miss single birds or birds of a particular species. Ground-based surveys ("ground truthing") conducted concurrently with aerial sur- veys can often detect these biases and, if biases are consistent over a number of replicates, a "correction factor" based on the average ratio of counts between the survey types can be determined to account for birds likely missed by aerial observers.

**Point counts**

Point counts are another of the most commonly used survey techniques for determining avian species composition and abundance. Point counts are essentially strip transects of zero length in which the observer performs the count in a 360° arc around a fixed survey station. Survey stations are randomly located throughout the study area to obtain repre- sentative samples of the species and numbers of each species present. If density estimates are desired from point counts, the counts are limited to objects within a fixed radius from the survey point. In such cases, the sampled plot becomes a circular plot of specified radius from the survey point (Figure 6.4).

As related survey techniques, many of the issues discussed for strip transects also apply to point counts. However, some important differences should be noted. Unlike strip transect surveys, point counts are usually conducted for a pre-determined and fixed period time, usually after allowing for the avian population to come to "rest" before the survey begins. Point counts are limited to ground- and boat-based surveys because observers must remain at the fixed count station.

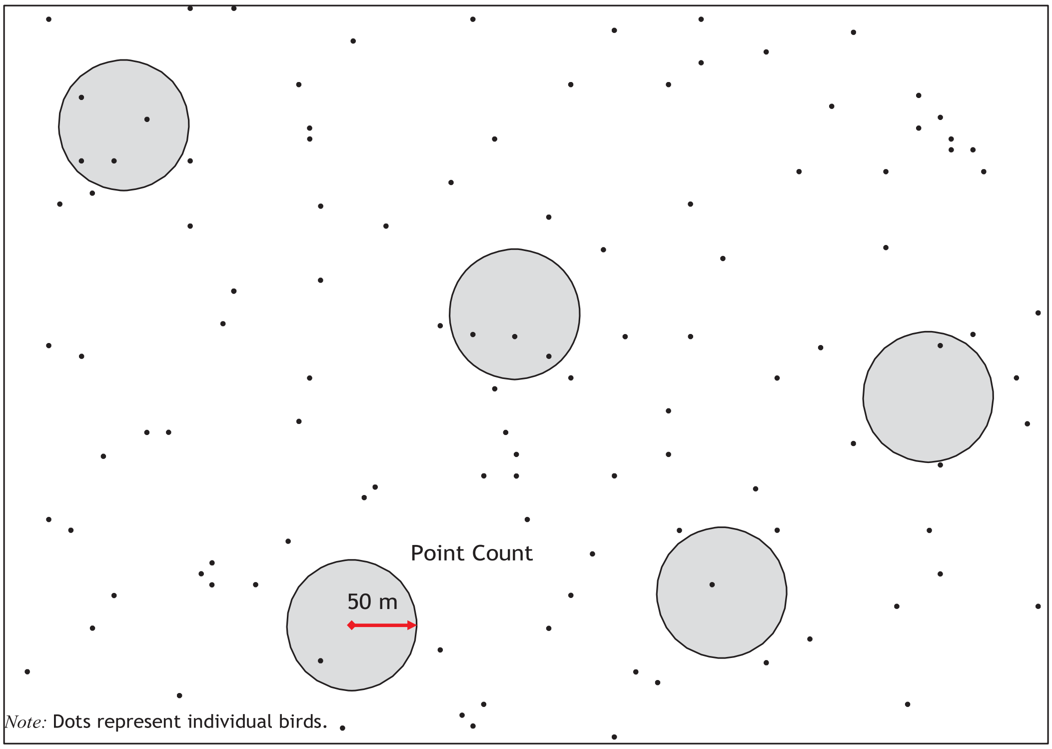
Point count surveys have been developed for a variety of species and habitats which may not be effectively surveyed with other survey techniques. Point counts are especially useful in difficult terrain where it is not be possible to establish practical transects or perform counts while travelling along the transect line; for example ground-based surveys of wetland birds in shallow marshy habitat with soft substrates, or surveys in steep terraced agricultural fields.

Because point count observers are sedentary, they may be more likely to detect shy spe- cies that would otherwise hide and escape detection when mobile and conspicuous strip transect observers approach. Thus, point counts can be used to inventory shy and retiring "bridge" species in the immediate vicinity of poultry farms and disease outbreak sites.

Point counts based on vocal cues have been developed for situations where visual cues are limited, such as nocturnal surveys or heavily vegetated habitats. For some species, vocal cues may be the only reliable means of detection; for example, most counts of secretive rails in heavily vegetated marshes have relied on vocal cues for determining their presence and abundance. However, distances from the point count station are often difficult to determine from vocal cues, making density estimates problematic.

FIGURE 5.4

**Use of point counts for estimating avian density and abundance**




*Note:* Dots represent individual birds.

## Distance sampling

Several studies have demonstrated that a significant proportion of animals within a defined plot are overlooked during strip transect and point counts, particularly those located at distance from the transect line or survey point. Distance sampling offers an alternative to these techniques that takes into account the decreasing probability of detecting animals as distance from the observer increases. In theory, distance sampling provides more reliable density estimates and should be considered when reliable absolute density or abundance estimates (as opposed to relative measures) are important objectives of the study.

Distance sampling survey techniques are similar to strip transect and point counts, with one major exception; distance data (recorded as perpendicular distances from the transect line or radial distances from point count station) are recorded for each animal (or group of animals) observed (Figure 5.5).

Unlike strip transect or point counts, distance sampling does not assume that all indi- viduals within a defined area are detected, but three assumptions need to be satisfied before distance sampling methodology can be used: 1) all objects on the line or point must be detected; 2) objects must be detected at their initial location, prior to any movement in response to the observer; and 3) distances must be measured accurately. In addition, a sufficient sample of observations is needed to model the detection function adequately. However, if the above assumptions and sample requirements can be met, then it is likely that distance sampling will yield more reliable population estimates than analogous esti- mates from strip transects and point counts.

The computer software program DISTANCE (Thomas *et al.* 1998) uses distance data to generate a detection function that models the decreasing probability of detecting an object as distance increases. DISTANCE is a very user-friendly program and offers a variety of input and analysis options, although a detailed review of distance sampling methodol- ogy is beyond the scope of this Manual. An excellent introduction to distance sampling by Buckland *et al.* (2001) provides background information and discussion of relevant issues such as model selection, data grouping and truncation, counting groups versus individuals and much more.

**Capture-mark-recapture**

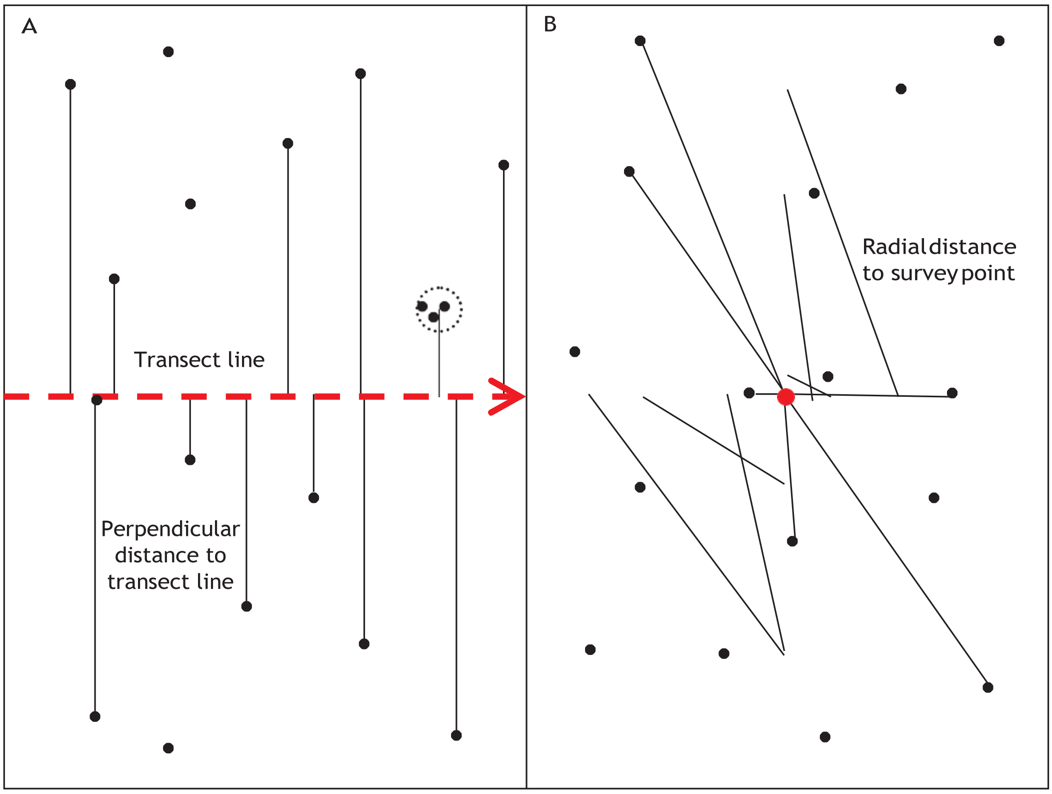
Capture-mark-recapture (CMR) studies have a long history of use for estimating popula- tion abundance, and a considerable body of literature has been dedicated to the use of CMR models. The basic theory underlying CMR modelling, in its simplest form, can be summarised as follows. Within a closed population of animals $(N)$, two samples ($n1$ and $n2$), are captured, marked and released at times 1 and 2, such that the number of marked animals recaptured at time 2 ($m2$) can be accurately determined. Intuitively, the proportion of marked animals recaptured in the second sample ($m2 / n2$) should equal the proportion of the total animals captured at time 1 in the total population ($n1 / N$), or alternatively $N = n1\ n2 / m2$ , where $N$ equals the total population size.

This basic model, the Lincoln-Petersen model, makes several assumptions that very few natural populations can meet. However, a number of modifications on this basic theme have been developed to permit CMR analyses even when the basic assumptions above are violated.

An in-depth discussion of all the different models is beyond the scope of this Manual, but references to several useful reviews are included at the end of the chapter for those seeking further information on CMR modelling. The computer program CAPTURE (Rexstad and Burnham, 1991) includes modifications of the Lincoln-Petersen model that provide population estimates with CMR data which account for unequal capture probabilities. The Jolly-Seber model is the basic CMR model for population estimates of open populations.

Programs which provide Jolly-Seber population estimates from CMR data include POPAN (Arnason and Schwartz, 1999), JOLLY (Pollock *et al*. 1990) and MARK (White and Burnham, 1999).

FIGURE 5.5
**Use of distance sampling for estimating avian density and**




*Note:* Dots represent individual birds

## References and information sources

**Arnason, A.N. & Schwartz, C.J.** 1999. Using POPAN-5 to analyse banding data. *Bird Study*, 46: S157-168.

**Bibby, C.J., Burgess, N.D., Hill, D.A. & Mustoe, S.H.** 2000. *Bird Census Techniques*. 2nd edition. Academic Press, London.

**Bibby, C., Jones, M. & Marsden, S.** 1998. *Expedition Field Techniques: Bird Surveys*. Royal Geographical Society, London.

**Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. & Thomas, L.** 2001. *Introduction to distance sampling, estimating abundance of biological popula- tions*. Oxford University Press, London.

**Delany, S.** 2005a. *Guidelines for participants in the International Waterbird Census (IWC).* Wetlands International, Wageningen, The Netherlands. (available at http://www.wet- lands.org).

**Delany, S.** 2005b. *Guidelines for National Coordinators of the International Waterbird Census (IWC).* Wetlands International, Wageningen, The Netherlands. (available at http://www.wetlands.org).

**Javed, S & Kaul, R.** 2002. *Field Methods for Bird Surveys.* Bombay Natural History Society, Mumbai, India.

**Lancia, R.A., Kendall, W.L., Pollock, K.H. & Nichols, J.D.** 2005. Estimating the number of animals in wildlife populations. *In* C.E. Braun, ed. *Techniques for wildlife investiga- tions and management*, pp. 106-153. The Wildlife Society, Bethesda, USA.

**Pollock, K.H., Nichols, J.D., Brownie, C. & Hines, J.E.** 1990. *Statistical inference for capture-recapture experiments.* Wildlife Monographs No. 107. The Wildlife Society, Bethesda, USA.

**Rexstad, E. & Burnham, K.P.** 1991. *User's guide for interactive program CAPTURE.* Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, USA.

**Thomas, L., Laake, J.L., Derry, J.F., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Strindberg, S., Hedley, S.L., Burt, M.L., Marques, F., Pollard, J.H. & Fewster, R.M.** 1998. *Distance 3.5.* Research Unit for Wildlife Population Assessment, University of St. Andrews, St Andrews, UK.

**White, G.C. & Burnham, K.P.** 1999. Program MARK: survival rate estimation from both live and dead encounters. *Bird Study*, 46:S120-139.

**Worden, J., Cranswick, P.A, Crowe, O., Mcelwaine, G. & Rees, E.C.** 2006. Numbers and distribution of Bewick's Swan *Cygnus columbianus bewickii* wintering in Britain and Ireland: results of international censuses, January 1995, 2000 and 2005. Wildfowl . 56: 3-22 (also available at www.wwt.org.uk/research/pdf/worden_et_al_2006.pdf).

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# 6 Herpetology

## Sexing Snakes

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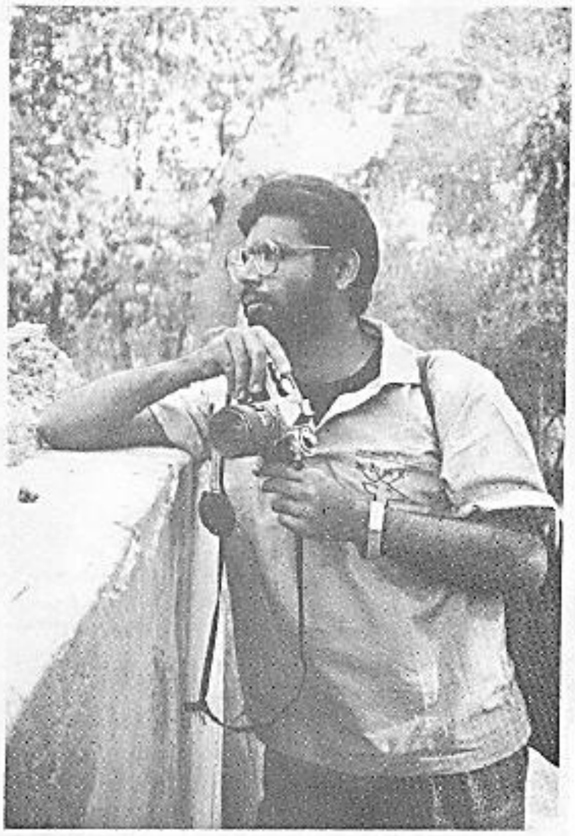

The snake Ophidia belongs to the class Reptilia. Snakes have long, slender, rope-like bodies and lack feet. In many zoos and small snake parks, snakes are kept as captive animals, and it is best if they are kept in pairs or as per sex ratio. This is also better for the species as you can observe their behaviour and, with a little more management, you can breed them.

There are three well-known methods of sexing the snake, but they can be difficult as well as risky and dangerous. In order to sex a snake you must catch the animal very gently and carefully.

**1. External characteristics**

a) Many primitive snakes have a vestigical organ called the pelvic girdle. In pythons, there are two spur-like structures on either side of the anal opening. The spur is always longer in the male than in the female. On that comparison of spur size you can make an assumption about the sex.

b) Most snake species have variation in body proportion which can help you to decide if an animal is male or female. There are more sub-caudal scales on the male than on the female, however in some species the female has a longer tail than the male (for example, the vine snake).

**2. Checking the sexual organs**

In all snake species there is a pair of penises known as the hemipenis. The hemipenis is located in the panial pocket of the tail. The snake must be caught very gently - for this you will require an assistant. One person holds the snake around the head region (be careful if this is a poisonous species) and another person holds the snake's tail. Very gently you rub the tail part from lower to upper side which will immediately cause the penis to come out of the anal opening. If no penis appears then the snake is female. The problem with this method is that some males may not show the correct response so you may make the wrong assumption.

**3. Probing**

For this method of sexing you use a small rod-like instrument. This rod should be metal or plastic. The thickness of the rod is very important - is should not be more than the thickness of the tail divided by 20 or 15. Both ends of the probe must be completely blunt, not sharp. One end of the probe is inserted into the penial pocket in the tail. (When you push the snake's anal plate towards the tail, you will find two holes at the edge). The probe will go deeper into a male snake. If the probe only goes to about 3.5cm at the sub-caudal plate, then the animal is female.

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CONSERVATION AND NATURAL HISTORY

METHODS

# Amphibian and Reptilian Inventories Augmented by Sampling at Heronries

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**Abstract.**—An alternate method for supporting amphibian and reptilian inventory was tested. This experimental method involved the collection of regurgitated food from water bird nestlings from a total of 10 heronries: four mixed-species and six single-species heronries in Gujarat State, India, during 1997 to 1999. We verified the presence of twelve species of amphibians, and twelve species of reptiles were recovered intact.

Various methods are used to evaluate the diversity of amphibians and reptiles, many of which are resource-dependent in terms of both time and money (e.g., Heyer et al. 1994). The verification process in such diversity surveys generally requires the collection of voucher specimens for establishing the credibility of the work (Dubois and Nemesio 2007; Funk et al. 2005). Vouchers also facilitate further taxonomic studies and the identification of cryptic species, especially when species complexes occupy the area being surveyed. The collection of specimens requires permission from the appropriate government authority. Because relevant authorities in India often are hardcore believers of the philosophy of "*Jiv Daya*" (a Jainist concept involving compassion for all beings) and unaware of the need for voucher specimens, acquisition of permits to collect in protected areas (sanctuaries and national parks), even for studies of biodiversity and environmental assessments is extremely difficult. Even when permission for voucher collection is granted, strict time constraints are imposed. These render surveys of large areas almost impossible, particularly because vouchers ideally involve a series of specimens of various species (Goodman and Lanyon 1994) and collection methods often are very time consuming. Consequently, methods that are less time-consuming and less expensive are needed. Herein, we test one such alternative.

## Materials and Methods

We collected amphibians and reptiles from heronries of egrets, herons, and cormorants, using hand-captures supplemented by a technique more commonly employed by ornithologists for obtaining data on the food spectrum of such birds (e.g., Seigfried 1971; Jenni 1973; Kushlan 1978). The diet of many egrets and herons consists of various types of insects, along with fishes, amphibians, reptiles, and mammals (Kushlan 1978; Sodhi 1992; Mathew et al. 1997). Especially during the breeding season, 45% of the diet of these species can comprise amphibians and reptiles (Sodhi and Khera 1984). These birds are widely distributed in many parts of the world, including the Indian Subcontinent, and all are colonial breeders. In India, the breeding season more or less coincides with the southwest monsoon (Ali and Ripley 1983), which also is the breeding season of many species of amphibians (Chandra 2002; Das and Dutta 2007) and reptiles (Daniel 2002).

Like other herons and egrets, frightened nestlings of Cattle Egrets will regurgitate food stored in the crop and gizzard (Hanebrink and Denton 1969; Jenni 1969). Because this is the least invasive method of studying the food consumed by nestlings (Patel 1996), they were frightened by striking a bamboo or lightweight aluminum pole against a tree branch while simultaneously shouting or clapping. Nestlings responded by immediately regurgitating a bolus, which was carefully collected, stored in a plastic bottle, preserved in a 5–10% formalin solution, labeled, and taken to the laboratory for further study.

To test the efficacy of this method for conducting surveys, we made observations and collected boluses during the southwest monsoon (July–September) in 1997, 1998, and 1999 at ten heronries (Fig. 1), four along the margins of protected areas and six in urban areas. Four heronries were mixed-species and six were single-species heronries (exclusively Cattle Egrets). However, even in the mixed-species heronries, Cattle Egrets were the most abundant species (Table 1) and the only one that is largely a terrestrial feeder (Hancock and Kushlan 1984). Cormorants, herons, and other egrets feed primarily in aquatic habitats (Ali and Ripley 1983).

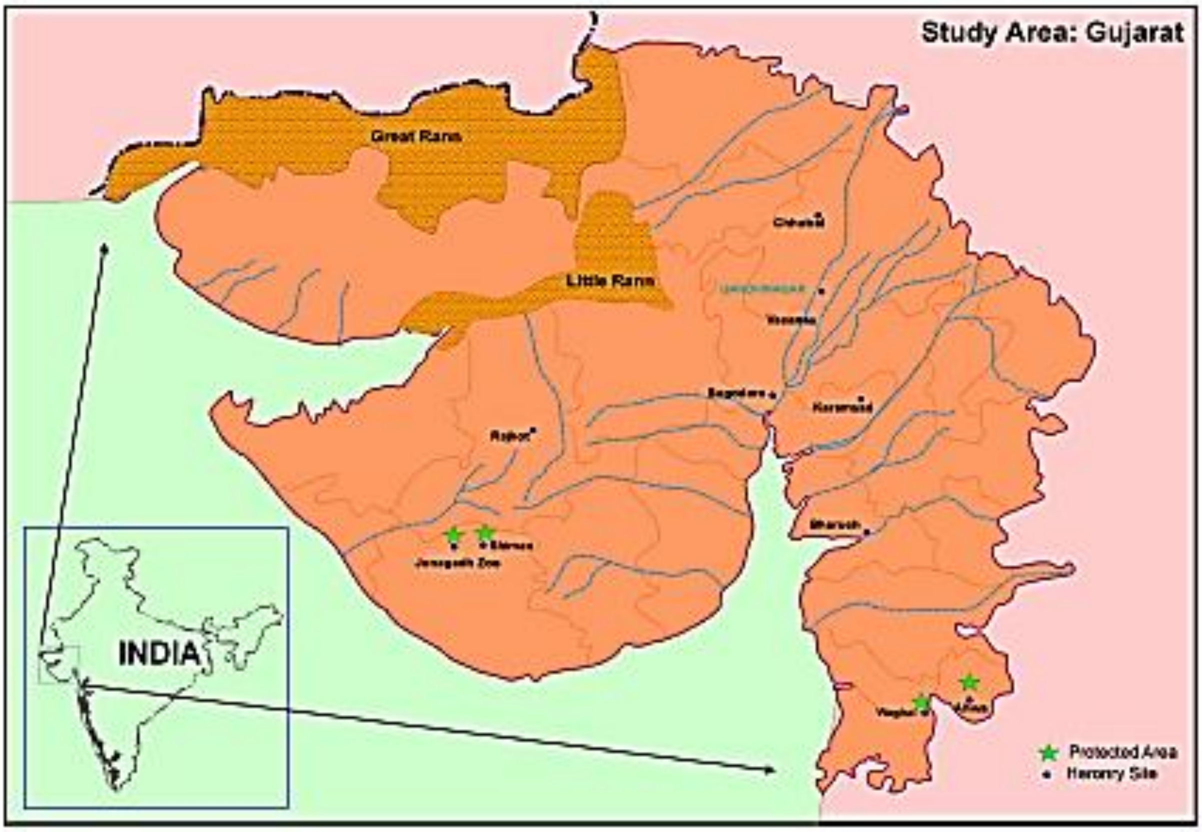


Fig. 1. The study area in Gujarat State showing the location of surveyed heronries (see also Table 1).

### Results

We collected 24 species of amphibians and reptiles, including 12 species of frogs and toads, one species of turtle, eight species of lizards, and three species of snakes (Table 2). Twelve species were in regurgitated food boluses, four of which (*Microhyla ornata*, *Euphlyctis hexadactylus*, *Eutropis carinata*, and *Eutropis macularia*) were found in four or more heronries, five (*Polypedates maculatus*, *Lygosoma albopunctata*, *Lygosoma guentheri*, *Amphiesma stolata*, and *Xenochrophis piscator*) in only two heronries, and three (*Ramanella* sp., *Lissemys punctata* hatchlings, and an adult *Echis carinata*) were limited to small areas within a single heronry.

The greatest numbers of amphibian and reptilian species were recovered from large and medium-sized single-species heronries at Waghai (20 species) and Ahwa (19 species), respectively (Table 1). Although both Bharuch and Waghai are large heronries, more species were recovered from the single-species heronry at Whagai than from the mixed-species urban heronry at Bharuch (14). The least number of species was recovered from a small single-species urban heronry in Rajkot (7).

### Discussion

Food habits of Cattle Egrets are catholic (Hancock and Kushlan 1984), hence the great diversity of reptiles and amphibians in the diet (Figs. 2 & 3). However, Cattle Egrets are terrestrial and rarely feed in marshy areas, reducing the likelihood of feeding on purely aquatic vertebrates. Consequently, small terrestrial vertebrates dominate their diet. On the other hand, cormorants, herons, and the other egrets feed primarily on aquatic organisms (fishes, occasional amphibians and aquatic snakes like the Buff-striped Keelback, *Amphiesma stolata*). With the exception of the Indian Flapshell Turtle (*Lissemys punctata*), few small reptiles occur in marshy/shallow waters. This presumably accounts for the relatively low number of amphibian and reptilian species recovered from the Bharuch heronry when compared to that at Waghai (mixed-species heronry vs. single-species heronry) despite both being large in size.

The amphibian and reptilian species found in regurgitated boluses were common and widely distributed, except *Ramanella* sp., which is restricted to the Dang Forest south of the Narmada River in Gujarat (Vyas 1998, 2008). In con-

**Table 1.** Heronries in Gujarat State, India, surveyed during this study. Large heronries (>2,000 nests): medium (2,000–1,000 nests): small (<1,000 nests). Bird species: Indian Pond Heron (*Ardeola grayii*), Cattle Egret (*Bubulcus ibis*), Great Egret (*Casmerodius albus*), Little Egret (*Egretta garzetta*), Intermediate Egret (*Mesophoyx intermedia*), Black-crowned Night Heron (*Nycticorax nycticorax*), and Little Cormorant (*Phalacrocorax niger*).

| Site (Year of Survey) Coordinates | Bird Species | Size | Number of Prey Species in Boluses | Remarks |
|---|---|---|---|---|
| Junagadh Zoo (1997) | *Bubulcus ibis* | Medium | 14 | Near Protected Forest |
| 21°32'31.79"N | *Egretta garzetta* | | | (now Girnar Wildlife Sanctuary) |
| 70°27'56.18"E | *Phalacrocorax niger* | | | |
| Shirvan, Talala (1997) | *Bubulcus ibis* | Small | 14 | Settlement in Girnar Wildlife Sanctuary |
| | *Egretta garzetta* | | | |
| Rajkot City (1997) | *Bubulcus ibis* | Small | 7 | Urban area |
| 22°16'57.22"N | | | | |
| 70°49'19.74"E | | | | |
| Bagodara (1997) | *Bubulcus ibis* | Medium | 13 | Urban area |
| 22°38'17.41"N | | | | |
| 72°12'05.59"E | | | | |
| Chhatral (1997) | *Bubulcus ibis* | Medium | 12 | Rural area |
| 23°16'49.51"N | | | | |
| 72°26'47.74"E | | | | |
| Vasna Village (1997) | *Bubulcus ibis* | Small | 11 | Rural area |
| 22°59'02.14"N | | | | |
| 72°33'36.79"E | | | | |
| Karamsad (1997) | *Bubulcus ibis* | Medium | 16 | Urban area |
| 22°32'32.93"N | *Egretta garzetta* | | | |
| 72°54'20.89"E | *Phalacrocorax niger* | | | |
| Bharuch City (1997) | *Ardeola grayii* | Large | 14 | Urban area |
| 21°42'45.53"N | *Bubulcus ibis* | | | |
| 73°00'04.28"E | *Casmerodius albus* | | | |
| | *Egretta garzetta* | | | |
| | *Mesophoyx intermedia* | | | |
| | *Nycticorax nycticorax* | | | |
| Waghai, Dangs (1999) | *Bubulcus ibis* | Large | 20 | Near Vansada National Park |
| 20°46'27.50"N | | | | |
| 73°29'46.72"E | | | | |
| Ahwa, Dangs (1999) | *Bubulcus ibis* | Medium | 19 | Near Purna Wildlife Sanctuary |
| 20°45'01.17"N | | | | |
| 73°29'46.72"E | | | | |

**Fig. 2.** A foraging Cattle Egret (*Bubulcus ibis*) with a Common Asian Toad (*Duttaphrynus melanostictus*). Photographs by Kartik Upadhyay.

**Fig. 3.** A foraging Cattle Egret (*Bubulcus ibis*) with a juvenile Checkered Keelback (*Xenochrophis piscator*). Photograph by Manoj Thaker.

trast, those species found only in specific heronries either had restricted distributions or were commonly encountered only during the monsoons.

Few of the Indian studies on the diets of nestling Cattle Egrets (Sodhi 1992) or other water birds (Mukherji 1972; Sodhi 1985, 1986, 1989; Sodhi and Khera 1986) attempted to identify amphibians and reptiles at the species level. Hence, this is the first report in which amphibians and reptiles recovered from regurgitated food boluses of Cattle Egrets and other water birds are identified at that level.

Consumption of the Flap-shell Turtle (*Lissemys punctata*) by the Black-necked Stork (Vyas and Thaker 2014) and the Lesser Adjutant Stork (Sivasubramanian and Bhupathy 1991) is well documented. However, smaller birds like the Cattle Egret were not known to feed on these turtles, so this report represents a new record. Similarly, the consumption of a venomous adult Saw-scaled Viper (*Echis carinata*) by a Cattle Egret is noteworthy.

Cattle Egrets usually breed during the southwest monsoon in northwestern India, with slight deviations depending on local conditions (Ali and Ripley 1983; Parasharya and Naik 1990). Considering asynchronous nesting in a given heronry (Parasharya and Naik 1990) or an area (Breeden and Breeden 1982), heronries could be sampled repeatedly over a three-month monsoon period. Repeated sampling would increase the likelihood of encountering amphibian and reptilian species that are less abundant or appear only under specific conditions (rain, agricultural operations, etc.).

Every survey method has advantages and disadvantages. Limitations of this supplementary method include: (1) Specific habitats and microhabitats of amphibian and reptilian species cannot be determined; (2) chances of acquiring intact specimens are reduced; (3) sampling at heronries is possible only during the birds' breeding seasons; and (4) it is useful only for smaller and mostly terrestrial species. Advantages are: (1) It consumes less time and money; (2) it does not require permission to collect specimens (although permission might

**Table 2.** Species of amphibians and reptiles found in regurgitated food boluses in heronries in Gujarat State, India. Heronries (see also Table 1): Junagadh Zoo (J), Shirvan, Talala (S), Rajkot City (R), Bagodara (B), Chharal (C), Vasna Village (V), Karamsad (K), Bharuch City (BC), Waghai, Dangs (W), and Ahwa, Dangs (A). Species: Common Asian Toad (*Duttaphrynus melanostictus*), Indian Marbled Toad (*Duttaphrynus stomaticus*), Ornate Narrow-mouthed Frog (*Microhyla ornata*), Balloon Frog (*Uperodon* sp.), Marbled Balloon Frog (*Uperodon systoma*), Indian Skipper Frog (*Euphlyctis cyanophlyctis*), Indian Green Frog (*Euphlyctis hexadactylus*), Indian Bullfrog (*Hoplobatrachus tigerinus*), Indian Burrowing Frog (*Sphaerotheca breviceps*), South Asian Cricket Frog (*Zakerana* sp.), Common Indian Treefrog (*Polypedates maculatus*), Indian Flapshell Turtle (*Lissemys punctata*), Brook's House Gecko (*Hemidactylus* c.f. *brookii*), Oriental Garden Lizard (*Calotes versicolor*), Fan-throated Lizard (*Sitana* c.f. *ponticeriana*), White-spotted Supple Skink (*Lygosoma albopunctata*), Günther's Writhing Skink (*Lygosoma guentheri*), Dotted Writhing Skink (*Lygosoma punctata*), Keeled Indian Mabuya (*Eutropis carinata*), Bronze Mabuya (*Eutropis macularia*), Buff-striped Keelback (*Amphiesma stolata*), Checkered Keelback (*Xenochrophis piscator*), and Saw-scaled Viper (*Echis carinata*).

| Family | Species | J | S | R | B | C | V | K | BC | W | A |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FROGS (ANURA) | | | | | | | | | | | |
| Bufonidae | *Duttaphrynus melanostictus* | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| | *Duttaphrynus stomaticus* | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Microhylidae | *Microhyla ornata* | Y | | | | | | | Y | Y | Y |
| | *Uperodon* sp. | | | | | | | | | Y | |
| | *Uperodon systoma* | | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Dicroglossidae | *Euphlyctis cyanophlyctis* | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| | *Euphlyctis hexadactylus* | Y | Y | | | | | Y | | Y | |
| | *Hoplobatrachus tigerinus* | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| | *Sphaerotheca breviceps* | Y | Y | | Y | Y | Y | Y | Y | Y | Y |
| | *Zakerana* sp. | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| | *Zakerana* sp. | Y | Y | | Y | Y | | Y | Y | Y | Y |
| Rhacophoridae | *Polypedates maculatus* | | | | | | | | | Y | Y |
| TURTLES (TESTUDINES) | | | | | | | | | | | |
| Trionychidae | *Lissemys punctata* | | | | | | | Y | | | |
| LIZARDS (SQUAMATA) | | | | | | | | | | | |
| Gekkonidae | *Hemidactylus* c.f. *brookii* | Y | Y | | Y | | Y | Y | Y | Y | Y |
| Agamidae | *Calotes versicolor* | Y | Y | | Y | Y | Y | Y | Y | Y | Y |
| | *Sitana spinaecephalus* | Y | Y | | Y | Y | Y | Y | Y | Y | Y |
| Sphenomorphidae | *Lygosoma albopunctata* | | | | Y | | | | | Y | |
| | *Lygosoma guentheri* | | | | | | | | | Y | Y |
| | *Lygosoma punctata* | Y | Y | Y | | Y | Y | Y | Y | | Y |
| Mabuyidae | *Eutropis carinata* | | | | Y | | | Y | | Y | Y |
| | *Eutropis macularia* | Y | Y | | | | | | Y | Y | Y |
| SNAKES (SQUAMATA) | | | | | | | | | | | |
| Natricidae | *Amphiesma stolata* | | | | | | | | | Y | Y |
| | *Xenochrophis piscator* | | | | | | | Y | | | Y |
| Viperidae | *Echis carinata* | | | | Y | | | | | | |

be necessary to salvage dead specimens in protected areas); and (3) it can provide tentative data regarding the population status (abundant/ rare/presumably absent) of amphibians and reptiles within the sampled area.

To date, we have tested this supplementary survey technique only in Gujarat State, which has a moderate amphibian and reptilian species richness, with over 23 species of amphibians (Vyas 2005) and 114 species of reptiles (Vyas 2007). If tested elsewhere on the Subcontinent, we believe it is likely to detect a greater number of species.

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## Literature Cited

Ali, S. and S.D. Ripley. 1983. *Handbook of the Birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka.* Oxford University Press, Delhi, India.

Breeden, S. and B. Breeden. 1982. The drought of 1979–1980 at the Keoladeo Ghana Sanctuary, Bharatpur, Rajasthan. *Journal of the Bombay Natural History Society* 79: 1–37.

Chandra, S.K. 2002. *Hand Book. Indian Amphibians.* Zoological Survey of India, Kolkata.

Daniel, J.C. 2002. *The Book of Indian Reptiles and Amphibians.* Bombay Natural History Society/Oxford University Press, Bombay.

Das, I. and S.K. Dutta. 2007. Sources of larval identities for amphibians of India. *Hamadryad* 31: 330–358.

Dubois, A. and A. Nemesio. 2007. Does nomenclatural availability of nomina of new species or subspecies require the deposition of vouchers in collection? *Zootaxa* 1409: 1–22.

Funk, V.A., P.C. Hoch, L.A. Prather, and W.L. Wagner. 2005. The importance of vouchers. *Taxon* 54: 127–129.

Goodman, S.M. and S.M. Lanyon. 1994. Scientific collecting. *Conservation Biology* 8: 314–315.

Hancock, J.A. and J. Kushlan. 1984. *Heron Handbook.* Croom Helm, London.

Hendrink, E.L. and G. Denton. 1969. Feeding behavior and analysis of regurgitated food collected from the Cattle Egret *Bubulcus ibis* and the Little Blue Heron *Florida caerulea. Proceedings of the Arkansas Academy of Science* 23: 74–79.

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster. 1994. *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians.* Smithsonian Institution Press, Washington, DC.

Jenni, D.A. 1969. A study of the ecology of four species of herons during the breeding season at Lake Alice, Alachua County, Florida. *Ecological Monographs* 39: 245–270.

Jenni, D.A. 1973. Regional variations in the food of nestling Cattle Egrets. *Auk* 90: 821–826.

Kushlan, J.A. 1978. Feeding ecology of wading birds. *Wading Birds* 7: 249–297.

Mathew, K.L., K.V. Pathani, and D.N. Yadav. 1997. Cattle Egret *Bubulcus ibis* feeding on baby rats. *Journal of the Bombay Natural History Society* 94: 396–397.

Mukherjee, A.K. 1972. Food-habits of water-birds of the Sundarban, 24-Parganas District, West Bengal, India-III. Egrets. *Journal of the Bombay Natural History Society* 68: 691–716.

Parasharya B.M. and R.M. Naik. 1990. Ciconiiform birds breeding in Bhavnagar City, Gujarat: A study of their nesting and plea for conservation, pp. 429–445. In: J.C. Daniel and J.S. Serrao (eds.), *Conservation in Developing Countries: Problems and Prospects.* Bombay Natural History Society & Oxford University Press, Bombay, India.

Patel, T.V. 1996. Nesting ecology and food of the nestlings of Cattle Egret *Bubulcus ibis coromandus* (Boddaert). Unpubl. M.S. Thesis, Gujarat Agricultural University, Anand, India.

Seigfried, W.R. 1971. The food of the Cattle Egret. *Journal of Applied Ecology* 8: 447–468.

Sivasubramanian, C. and S. Bhupathy. 1991. Indian Flapshell Turtle *Lissemys punctata* in the food of the Adjutant Stork *Leptoptilos dubius. Journal of the Bombay Natural History Society* 87: 460.

Sodhi, N.S. 1985. Food of the Black-crowned Night Heron nestlings. *Pavo* 23: 47–52.

Sodhi, N.S. 1986. Feeding ecology of Indian Pond Heron and its comparison with that of Little Egret. *Pavo* 24: 97–116.

Sodhi, N.S. 1989. Monthly variations in diet of Cattle Egret *Bubulcus ibis coromandus* in and around Chandigarh. *Journal of the Bombay Natural History Society* 86: 440–443.

Sodhi, N.S. 1992. Food niche relationships of five sympatric north-Indian herons. *Forktail* 7: 125–130.

Sodhi, N.S. and S. Khera. 1984. Food, food requirement during growth and feeding behavior of nestling *Bubulcus ibis coromandus* (Boddaert). *Pavo* 22: 21–29.

Sodhi, N.S. and S. Khera. 1986. Feeding habits of the Median Egret. *Research Bulletin of the Panjab University of Science* 37(1–2): 9–12.

Vyas, R. 1998. The reptiles of Gujarat state: Updated distribution. *Tiger Paper* 25(1): 8–14.

Vyas, R. 2005. Vernacular name of amphibian fauna in the state of Gujarat. *Herpinstance* 3(1): 8–9.

Vyas, R. 2007. Present conservation scenario of reptile fauna in Gujarat State, India. *The Indian Forester* 133(10): 1381–1394.

Vyas, R. 2008. Review of the current diversity and richness of amphibians of Gujarat, India. *The Indian Forester* 134(10): 1381–1392.

Vyas, R. and M. Thaker. 2014. Note on predators of *Lissemys punctata* (Lacépède, 1788). *Sauria* 36: 75–78.

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# Reptiles of Gujarat, India: Updated Checklist, Distribution, and Conservation Status

Harshil Patel[1,*] and Raju Vyas[2]

**Abstract.** We present a revised checklist of reptiles inhabiting Gujarat, based on historical records and incorporating those from recent fieldwork. A total of 107 reptile species from 62 genera in 23 families was recorded. In addition, records for 23 species of reptiles dubiously or erroneously reported in the literature are discussed and recommended for removal from the Gujarat reptile list. Conservation status, threats, and endemism of recorded species are also discussed.

**Keywords.** Squamata, Crocodylia, Chelonia, Diversity, Distribution, Endemic, Western India

## Introduction

The westernmost state of India, Gujarat (ca. 20.21–24.80°N to 68.16–74.76°E), is one of the most biodiverse regions of the country. The political boundaries encompass a uniquely diverse geographical region that comprises a variety of habitat types, ranging from moist deciduous forests to deserts, and from freshwater wetlands to saline gulfs with mudflats and mangroves. Additionally, most of the major mountain ranges of Peninsular India, such as the Aravalli, Vindhya, and Satpura Ranges, as well as the Western Ghats (Sahyadri), have a terminus in Gujarat, and this, along with other different habitats, creates conditions that support a unique and diverse fauna (Vyas, 2007; Giri et al., 2009; Mirza et al., 2016). Studies on the reptile fauna of Gujarat are comparatively better than those on amphibians, fishes, or invertebrates, but they have lagged behind the progress made on the faunas of birds and mammals (Vyas, 2000a).

Our knowledge of Gujarat reptiles traces back to the 1870s (Stoliczka, 1872; Murray, 1886; Gleadow, 1887; McCann, 1938; Acharya, 1949; Kapadia, 1951; Daniel and Shull, 1963; Sharma, 1982, 2000; Gayen, 1999; Vyas, 1993, 1998, 2000a, 2007; Patel et al., 2018). However, a majority of these studies were restricted to selected regions of Gujarat and, with few exceptions (Vyas, 2000a, 2007), did not present the reptile fauna for the entire state (Vyas, 2000a). In recent years, several new species have been described and new records published, resulting in a rapid increase in the number of reptiles reported for the state (Vyas, 2000b, 2003, 2004a, 2005, 2017; Vyas and Desai, 2010; Vyas and Patel, 2007, 2013; Vyas and Prajapati, 2012; Vyas and Upadhyay, 2008; Vyas et al., 2006, 2011, 2017; Giri et al., 2009; Patel et al., 2015, 2016; Sharma and Jani, 2015; Mirza et al., 2016, 2018; Joshi et al., 2017; Agarwal et al., 2018). In contrast, some species have been listed as present in Gujarat based on historical records. The combination of new information and old records, some with questionable validity, prompted our reappraisal of Gujarat's reptilian fauna. Here, we provide a list of all reptile species that we have either documented ourselves or that we consider as having been reliably reported in the literature. We also advocate removal of some species dubiously or erroneously reported from Gujarat, pending reliable, correctly identified vouchers.

Study Area

The area of Gujarat State comprises 196,024 km2, of which 14,757 km2 is covered by forest (FSI, 2017). According to Champion and Seth (1968), the forests of Gujarat are divided into four major types, including 3B – south Indian moist deciduous forest; 4B – swamp forest; 5A – southern tropical dry deciduous forest; and 6B – northern tropical thorn forest. Gujarat has a very strategic location from a biogeographic point of view, as it covers four biogeographic zones of India and 40% of the total biogeographic diversity is represented in this state (Rodgers et al., 2002). The state is administratively divided in to 33 districts. For ease of understanding, we have divided the state into five geographical units, based on climatic variation, geology, forest types, soil, and drainage patterns (Figs. 1 and 2). These include (1) South Gujarat: This region is an extension of the northern end of the Western Ghats and can be divided into coastal plains and hilly moist deciduous forest. (2) Central Gujarat: This area is an extension of the western Satpura and Vindhya Ranges (Malwa Plateau) along with some central plains, featuring dry deciduous forest. It receives the drainage water of major rivers, such as the Narmada and Mahi. (3) North Gujarat: This region is an extension of the Aravalli Hills, with a mix of dry deciduous, Prossopis, and thorny scrub arid forest. (4) Saurashtra: This unit has the longest coastline of the five regions, and it includes two coastal gulfs with good mangrove forests. It also comprises large forest blocks of dry deciduous and thorny scrub forests alongside of grasslands. (5) Kutch: This is an area with large undulating hills area with scant rain, as well as dry arid and grasslands areas. It is bordered by the Greater and Little Rann of Kachchh .

The climate of Gujarat is tropical with three distinct seasons, namely the monsoon (mid-June–October), winter (October–February), and summer (March–mid-June). The southwest monsoon is irregular and erratic. The maximum rain is experienced during July, with occasional showers during November–January and March–May. The average rainfall varies between regions and ranges from 2800 mm in some areas of South Gujarat to as low as 400 mm in Kutch. Temperatures begin to increase beginning in the second half of February. May is the hottest month of the year, with mean daily maximum temperatures reaching > 45°C in Kutch, North Gujarat, and regions of Saurashtra. December is the coldest month of the year with a mean daily maximum temperature near 25°C and a mean minimum of < 10°C. Due to the passage of extratropical storms known as Western Disturbances across northern India during the cold season, spells of colder weather occur and the minimum temperature sometimes drops to about 2°C. The relative humidity is comparatively high in the monsoon season (data derived from the Indian Meteorological Department website, http://www.imd.gov.in).

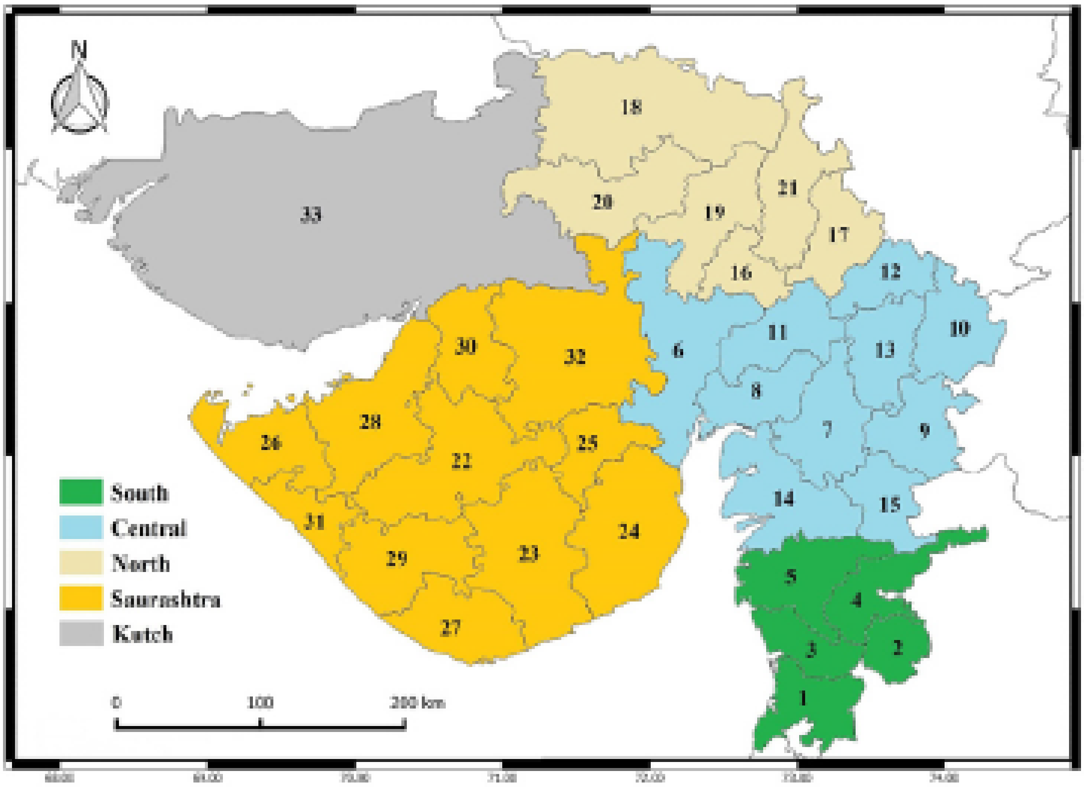


**Figure 1.** Administrative map of Gujarat State, India. Numbered areas correspond to administrative districts, which are as follows: Valsad (1), Dang (2), Navsari (3), Tapi (4), Surat (5), Ahmedabad (6), Vadodara (7), Anand (8), Chhota Udaipur (9), Dahod (10), Kheda (11), Mahisagar (12), Panchmahal (13), Bharuch (14), Narmada (15), Gandhinagar (16), Aravalli (17), Banaskantha (18), Mehsana (19), Patan (20), Sabarkantha (21), Rajkot (22), Amreli (23), Bhavnagar (24), Botad (25), Devbhoomi Dwarka (26), Gir Somnath (27), Jamnagar (28), Junagadh (29), Morbi (30), Porbandar (31), Surendranagar (32), Kachchh (33). The districts are in turn grouped by the indicated colours into the state's five geographic units.

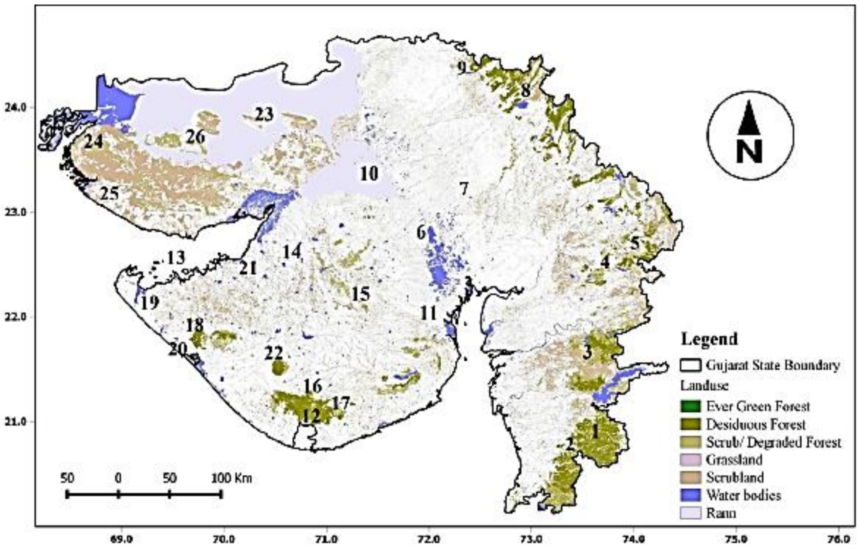


**Figure 2.** Geographical map of Gujarat State, India. Vegetation cover is indicated by colours, as described in the legend. Numbered areas correspond to Protected Areas [abbreviations include Wildlife Sanctuary (WS) and National Park (NP)], which are as follows: Purna WS (1), Vansada NP (2), Shoolpaneswar WS (3), Jambughoda WS (4), Ratanmahal WS (5), Nalsarowar WS (6), Thol WS (7), Balaram-Ambaji WS (8), Jassore WS (9), Wild Ass WS (10), Valavader NP (11), Gir NP & WS (12), Marine NP & WS (13), Rampara WS (14), Hingolgadh WS (15), Pania WS (16), Mitiyal WS (17), Barda WS (18), Gaga Bustard WS (19), Porbander Bird WS (20), Khijadiya WS (21), Girnar WS (22), Kutch Desert WS (23), Naryan Sarover WS (24), Kutch Bustard WS (25), Chhari-Dhandh WS (26).

## Material and Methods

The present survey includes the scientific literature up to April 2018 and the results from several field surveys in the different regions and territorial extensions of Gujarat conducted from 2012–2017. One of us (RV) has been actively surveying the reptilian fauna of the state for the past three decades. During field surveys, the study area was divided into various regions, and each region was explored on the basis of habitat types and the level of species diversity following Vyas (2004b). Many different techniques, including visual encounter surveys (VESs), pitfall traps, opportunistic collection, and nocturnal road cruising, were employed for data collection. Species encountered were collected, examined, and photographed in the field and released in the same area, except for selected vouchers to allow further study. All species were carefully identified using diagnostic keys and the available literature (e.g., Smith, 1931, 1935, 1943; Whitaker and Captain, 2004; Lajmi et al., 2016). Nomenclature follows the most recent taxonomic advances (e.g., Deepak et al., 2016; Lajmi et al., 2016; Agarwal et al., 2018; Mirza and Patel, 2018; Purkayastha et al., 2018; Takeuchi et al., 2018; Uetz et al., 2018). Taxa whose identity remains unresolved at the species level are listed with the notation "cf." before the species name, indicating similarity. The global threat assessment level for each species was obtained from the International Union for Conservation of Nature *Red List* (IUCN, 2018), except for the putative new species. We used the five different regions as defined above for our species listings (for details refer to Fig. 1).

**Results**

A total of 107 reptile species, belonging to 62 genera and 23 families, were identified for Gujarat (Table 1). We report one non-native species (*Trachemys scripta*) from the state, and as an invasive we did not include it in Table 1. We recorded one species of crocodile (Crocodylidae), nine species of chelonians belonging to five families, 43 species of lizards belonging to seven families, and 54 species of snakes belonging to ten families. Among the chelonians, Cheloniidae (three species) had the highest diversity, followed by Geoemydidae (two species) and Trionychidae (two species). Dermochelyidae and Testudinidae were represented by a single species each. Among lizards, the highest diversity was observed for Gekkonidae (16 species), followed by Scincidae (11 species), Agamidae (seven species), Lacertidae (five species), and Varanidae (two species). Species of Eublepharidae, and Chamaeleonidae also contribute to the species diversity, with each represented by a single species. Snakes were represented by Elapidae (14 species), Viperidae (three species), Typhlopidae (three species), Homalopsidae (two species), Lamprophiidae (two species), Erycidae (two species), Uropeltidae (two species), Pythonidae (one species), Acrochordidae (one species), and Colubridae (24 species), the latter with the highest diversity among snakes.

South Gujarat (75 species) was found to have the highest reptilian diversity among the five regions, followed by Saurashtra (74 species), Central Gujarat (71 species), Kutch (52 species), and North Gujarat (51 species) (Figs. 3, 4). Crocodylians were represented by *Crocodylus palustris,* which was reported from all five regions. Among chelonians, the family Dermochelyidae was represented by a single species, *Dermochelys coriacea*, reported from Kutch (in the Gulf of Kutch). The highest diversity of turtles was found in Central Gujarat and Kutch, each with six species. Saurashtra had the highest lizard diversity (26 species) and South Gujarat accounted for the highest number of snake species (46 species). The family Uropeltidae was reported only from South Gujarat. Gujarat has one endemic genus, the colubrid snake genus Wallaceophis, and three endemic species (Fig. 5), including *Hemidactylus gujaratensis* (Gekkonidae), *Ophisops kutchensis* (Lacertidae), and *Wallaceophis gujaratensis* (Colubridae). *Hemidactylus gujaratensis* a spot endemic species from Saurashtra, while *Ophisops kutchensis* occurs in parts of Kutch and Saurashtra. *Wallaceophis gujaratensis* is known from Saurashtra and Central Gujarat.

According to their IUCN status, 72 species (68%) are considered to be of Least Concern (LC), 20 (19%) are listed as Not Evaluated (NE), six (5%) as Vulnerable (VU), five (5%) as Data Deficient (DD), two (2%) as Critically Endangered (CR), and one (1%) as Endangered (EN) (Fig. 6).

**Species occurrences need to be verified**

We also determined that 23 species belonging to nine families reported in the literature were based on dubious or erroneous records, including historical reports, and need to be corrected.

*Turtles.*—In his account of reptiles of Kutch, McCann (1938:425) stated that "according to Captain V.C. Steer-Webster *Caretta caretta* comes ashore at Mandvi to breed." However, there are no reports other than this of *C. caretta* from Gujarat, and without any supporting evidence or a voucher specimen the record of this species cannot be verified and should be removed from the state's list of reptiles. Sharma (2000) reported *Geoclemys hamiltonii* and *Hardella thurjii* from South and North Gujarat, respectively, without any specimen vouchers or specific locality details but others (Vyas, 2000a, 2007; Patel et al., 2018) did not report these of *Lygosoma vosmaeri* in the collection of the Bombay Natural History Society (BNHS), Mumbai. We inquired about the specimen (BNHS 1975) in question and learned that the locality of its collection is actually unknown (Saunak Pal, pers. comm.). As a consequence, this species should not be included among the reptiles of Gujarat. Auffenberg et al. (1989) suggested a probable distribution of *Varanus flavescens* in Gujarat based on habitat suitability, but there are no confirmed records for the species in the state. Kumar (2009) reported *Varanus salvator* from Nalsarovar, but this species occurs only in parts of northeastern India and on the Andaman and Nicobar Islands (Uetz et al., 2018).

Snakes.—Sharma (2007) included Gujarat in the range of *Myriopholis blanfordi* without any further information. The region of Kutch is suitable for this species but a reliable report is lacking. *Uropeltis ocellata* was reported from the Narmada Valley by Naik et al. (1993) without any voucher. We believe this to be an error because *U. ocellata* is a localized endemic in southern India. In the past, a brown morph of Ahaetulla nasuta was erroneously identified as *A. pulverulenta* (Vyas, 1988), so *A. pulverulenta* is not confirmed for Gujarat. Naoroji and Monga (1983) reported *Atretium schistosum* without further evidence as a prey item of the serpent eagle, *Spilornis cheela*, in Rajpipla, Gujarat. The article lacked additional details on the snakes species. As a consequence, we consider both records dubious. *Melanochelys trijuga* was reported to occur in forests of Dangs, South Gujarat (Daniel and Shull, 1963; Vyas and Patel, 1990), but more recently this species has become regionally extinct in Gujarat (Vyas, 2007; Patel et al., 2018). Two turtles, *Nilssonia leithii* and *Pangshura tentoria*, were historically reported from South Gujarat (Bhatt, 1989; Frazier and Das, 1994). However, neither species has been reported since then, and vouchers would be needed to confirm their continued existence in the state.

*Lizards.*—Vyas (2000a) included *Eumeces schneideri* in the list of reptiles of Gujarat and erroneously cited Stoliczka (1872) as the author reporting it from Kutch. While the habitat in Kutch is suitable for the species, a reliable, recent report is lacking. Datta-Roy et al. (2014)

mentioned the existence of a Gujarat specimen of *Lygosoma vosmaeri* in the collection of the Bombay Natural History Society (BNHS), Mumbai. We inquired about the specimen (BNHS 1975) in question and learned that the locality of its collection is actually unknown (Saunak Pal, pers. comm.). As a consequence, this species should not be included among the reptiles of Gujarat. Auffenberg et al. (1989) suggested a probable distribution of *Varanus flavescens* in Gujarat based on habitat suitability, but there are no confirmed records for the species in the state. Kumar (2009) reported *Varanus salvator* from Nalsarovar, but this species occurs only in parts of northeastern India and on the Andaman and Nicobar Islands (Uetz et al., 2018).

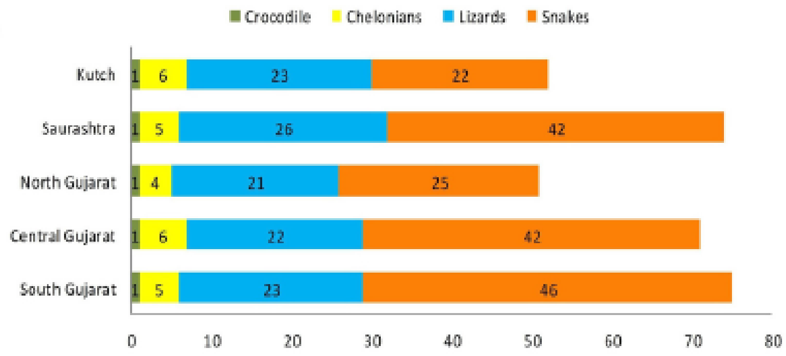


**Figure 3.** Graph illustrating the species composition in the five major regions of Gujarat.

*Snakes.*—Sharma (2007) included Gujarat in the range of *Myriopholis blanfordi* without any further information. The region of Kutch is suitable for this species but a reliable report is lacking. *Uropeltis ocellata* was reported from the Narmada Valley by Naik et al. (1993) without any voucher. We believe this to be an error because *U. ocellata* is a localized endemic in southern India. In the past, a brown morph of *Ahaetulla nasuta* was erroneously identified as *A. pulverulenta* (Vyas, 1988), so *A. pulverulenta* is not confirmed for Gujarat. Naoroji and Monga (1983) reported *Atretium schistosum* without further evidence as a prey item of the serpent eagle, *Spilornis cheela*, in Rajpipla, Gujarat. The article lacked additional details on the snakes reported as the prey items of *S. cheela* and we believe there was most likely a misidentification with *Fowlea piscator*, a common species of the region. Wall (1924) mentioned a skin of *Ophiophagus hannah* with an origin in Deesa, Palanpur, North Gujarat. We believe this was most likely from a captive specimen, transported by a snake charmer or other human activities. The nearest confirmed location for the species is Tillari in southern Maharashtra (Yadav and Yankanchi, 2015), nearly 1000 km away. Stoliczka (1872) reported *Psammophis schokari* from Kutch, and this remains the sole report of this species from Gujarat. While the habitat in Kutch and some other regions in North Gujarat is suitable for this species, a fresh voucher is needed to confirm its continued presence in the state. In his account on reptiles of Gujarat, Gayen (1999) considered the possibility that *Hydrophis lapemoides* occurred in the coastal regions but a confirmed report is lacking. *Dendrelaphis pictus*, *Oligodon venustus*, *Psammophis condanarus*, and *Naja oxiana* have been reported in the literature without any vouchers or morphological details (Murray, 1886; Kapadia, 1951; Akhtar and Tiwari, 1991; Patel and Reddy, 1995) and should be removed pending reliable, correctly identified vouchers. Wallach et al. (2014) erroneously included Gujarat in the range of *Boiga cynodon*. This is a Southeast Asian species and does not occur in India (Uetz et al., 2018). Recently, Sharma and Jani (2015) reported *Lycodon travancoricus* from the Vansda National Park, Navsari. The report was based on two images without any morphometric or scalation data. Despite being a common snake throughout its range in the Western Ghats (Zeeshan Mirza, pers. comm.; HP, pers. obs.), this species was not found during the present or previous studies (Vyas 2004b, 2007; Patel et al., 2018). A fresh voucher specimen is needed to further confirm the occurrence of this species in the state.

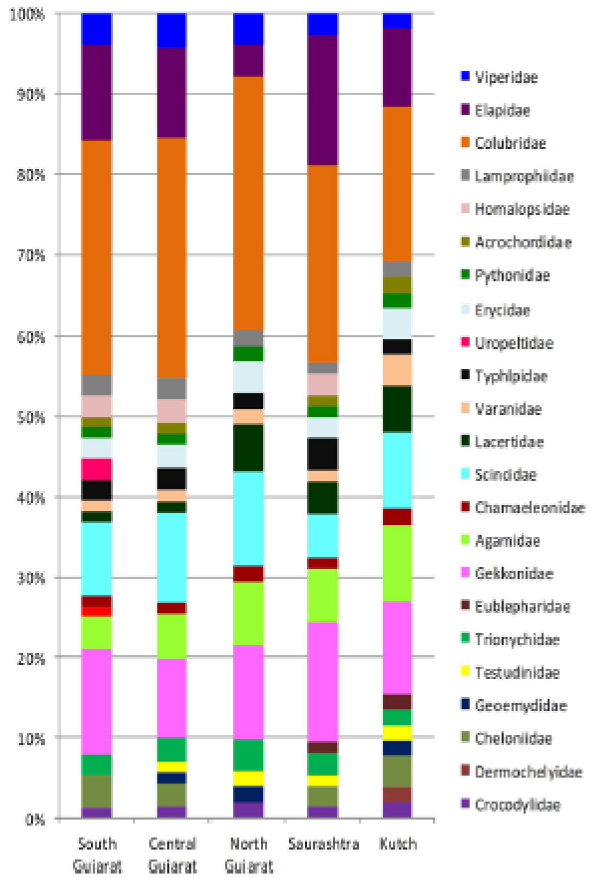


**Figure 4.** Bar graph showing the reptilian families represented in each of the five major regions of Gujarat State, India.

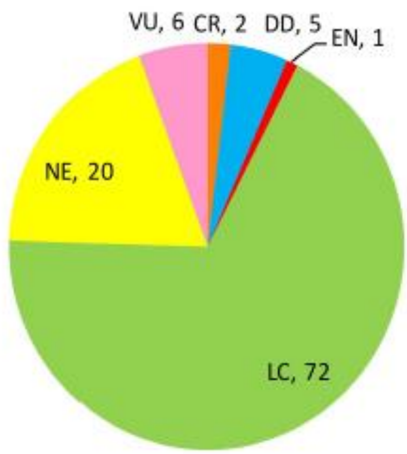


**Figure 6.** Pie chart illustrating the IUCN conservation status of reptiles of Gujarat, India. Integers indicate the percentage of Gujarat reptiles with the displayed status. Abbreviations include Not Evaluated (NE), Least Concern (LC), Data Deficient (DD), Vulnerable (VU), Endangered (EN), and Critically Endangered (CE).

**Discussion**

The present number of reptile species of Gujarat now stands at 131, a number that includes 23 erroneously or dubiously reported species and one non-native species (*Trachemys scripta*), a significant increase for the state (107 in Vyas, 2000a; 114 in Vyas, 2007) (Fig. 7). Of these, the identity of *Cyrtopodion* sp. from Central Gujarat remains unclear and this appears to be a new species, but further sampling and taxonomic studies are necessary to produce a firm assessment (Agarwal et al., 2014).

The Saurashtra region accounts for the highest number of Gujarat endemic species, with all three species reported from Saurashtra. Other than Gujarat endemics, many species are reported from only a single region in Gujarat. *Dermochelys coriacea*, *Batagur baska*, *Ophiomorus raithmai*, and *Varanus griseus* have been reported only from Kutch. *Hemidactylus gujaratensis*, *H. robustus*, *Indotyphlops porrectus*, *Hydrophis cantoris*, *H. gracilis*, *H. mamillaris*, and *H. spiralis* have been reported only from Saurashtra. *Hemidactylus persicus* and *Ophisops pushkarensis* are reported only from North Gujarat. *Psammophilus blanfordanus* and *Eutropis dissimilis* are reported only from Central Gujarat. *Cyrtodactylus deccanensis*, *Hemidactylus gracilis*, *H. maculatus*, *Monilesaurus rouxii*, *Uropeltis ellioti*, *U. macrolepis*, *Boiga beddomei*, *Chrysopelea ornata*, and *Calliophis nigrescens* are reported only from South Gujarat. Recently, Mohan et al. (2018) synonymised *Elachistodon* with *Boiga* based on preliminary molecular phylogeny study. However, their results show that *Boiga* is paraphyletic and a detailed phylogenetic study is underway. For the purposes of the present list, we have retained *Elachistodon* as a distinct genus. Previously, *Platyceps gracilis* was reliably reported from Central Gujarat only (Vyas et al., 2011), but more recently we have received evidence and specimens from South and North Gujarat. The species appears to be distributed throughout the hilly forest belt of eastern Gujarat. Similarly, *Wallophis brachyura* was previously known only from Surat, South Gujarat (Patel et al., 2015) but recently a specimen was collected at Dabhoi, near Vadodara (Central Gujarat). A relict population of *Chrysopelea ornata* was confirmed from the forests of Dangs (Patel et al., 2018); a report from Rajkot (Buch, 1999) appears to be of a specimen introduced in this region by anthropogenic activities, most likely timber transportation. The species *Coelognathus helena* is represented by two subspecies. Whereas *C. h. helena* occurs throughout the state, *C. h. monticollaris* is restricted to the forested regions of South Gujarat (Mohapatra et al., 2016). Similarly, *Echis carinatus* appears to be represented by two subspecies, *E. c. carinatus* distributed throughout the state and *E. c. sochureki* occurring in Kutch and parts of North Gujarat (Whitaker and Captain, 2004). There are few reports of a non-native species, *Trachemys scripta* (Fig. 8) from the state (Munjpura, 2014; Vyas, 2015). It is a well-known pet species and must have been released by or escaped from pet owners or vendors. A survey is necessary to determine the exact range of *T. scripta* in the state and its effects on the native fauna.

Of the reported 107 reptile species of Gujarat, the Red List status of 20 has not been evaluated or listed, 72 are listed as Least Concern, and five are considered data deficient. The plausible reason for this high aggregate number of species in these three categories could be lack of information on population size, reduction trends, and accurate distribution, both locally for Gujarat but also more generally. Clearly, the status of reptiles in this region lacks detailed studies. We have documented many direct and indirect threats to reptiles, including vehicular impact/transportation, habitat destruction and alteration, soil erosion, soil and water pollution, poaching or hunting, destructive agricultural practices, irrigation practices, forest fire, and even consumption as food by local tribal communities. Many of these threats we have reported earlier (Vyas, 2007; Patel et al., 2018), but an impact assessment of each of these threats is necessary to improve conservation policies.

Gujarat supports a high number of reptiles due to its high habitat diversity. While Gujarat accounts for < 6% of the geographical area of India, it includes nearly 20% of the country's known reptilian diversity. Many regions of Gujarat remain largely unexplored in terms of reptilian studies. Studies involving systematic surveys of each region, along with incorporation of detailed taxonomic comparisons, may yield additional reptilian discoveries in Gujarat.

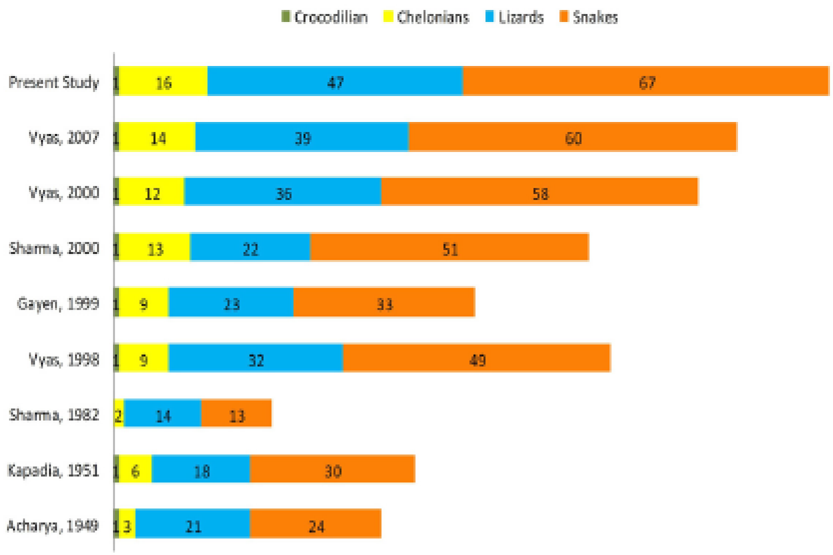


**Figure 7.** Bar graph showing total number of reptilian species reported during present and previous studies.

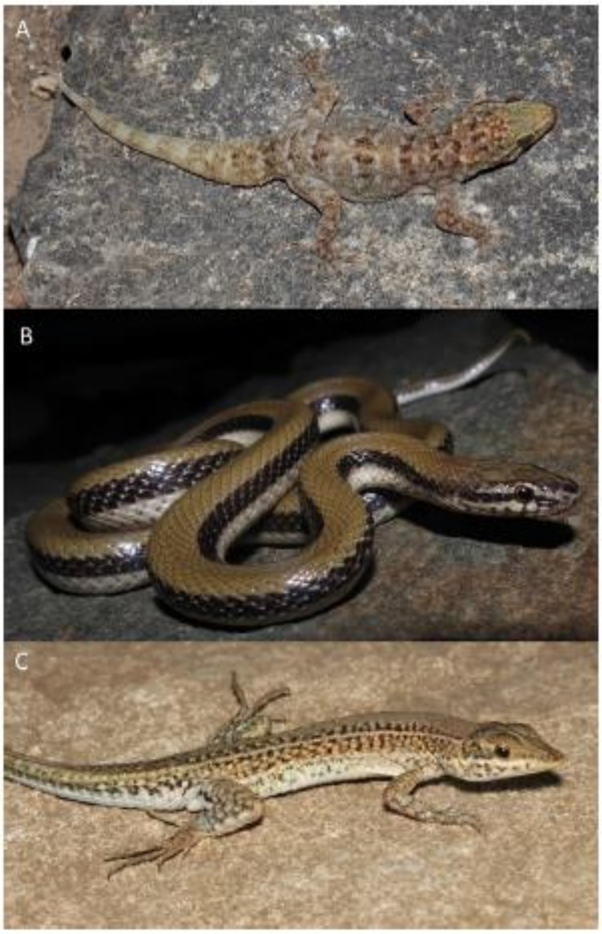


**Figure 5.** Endemic reptiles of Gujarat State, India. (A) *Hemidactylus gujaratensis* from Mt. Girnar, Junagadh. (B) *Wallaceophis gujaratensis* from Viramgam, Ahmedabad. (C) *Ophisops kutchensis* from Dwarka. Photos by Harshil Patel.

**Figure 8.** Live individual of *Trachemys scripta* from Chikhli, Gujarat, India. Photo by Harshil Patel.

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**Table 1.** Systematic list of Reptiles of Gujarat State, India with indication of their regional distribution. Abbreviations include S – South Gujarat, CG – Central Gujarat, NG – North Gujarat, SAU – Saurashtra, and KU – Kutch. An asterisk (*) indicates a spec endemic to Gujarat. Species present in each region are denoted using the letter 'P'.

| Sr No | Species | IUCN status | SG | CG | NG | SAU | KU |
|---|---|---|---|---|---|---|---|
| | **Turtles** | | | | | | |
| | **Family: Geoemydidae** | | | | | | |
| 1 | *Batagur baska* (Gray, 1831) | CR | | | | | P |
| 2 | *Pangshura tecta* (Gray, 1831) | LC | | P | P | | |
| | **Family: Testudinidae** | | | | | | |
| 3 | *Geochelone elegans* (Schoepff, 1795) | VU | | P | P | P | P |
| | **Family: Trionychidae** | | | | | | |
| 4 | *Lissemys punctata* (Bonnaterre, 1789) | LC | P | P | P | P | P |
| 5 | *Nilssonia gangetica* (Cuvier, 1825) | VU | P | P | P | P | |
| | **Family: Cheloniidae** | | | | | | |
| 6 | *Chelonia mydas* (Linnaeus, 1758) | EN | P | P | | P | P |
| 7 | *Eretmochelys imbricata* (Linnaeus, 1766) | CR | P | | | | |
| 8 | *Lepidochelys olivacea* (Eschscholtz, 1829) | VU | P | P | | P | P |
| | **Family: Dermochelyidae** | | | | | | |
| 9 | *Dermochelys coriacea* (Vandelli, 1761) | VU | | | | | P |
| | **Lizards** | | | | | | |
| | **Family: Agamidae** | | | | | | |
| 10 | *Calotes minor* (Hardwicke & Gray, 1827) | DD | | P | P | P | P |
| 11 | *Calotes versicolor* (Daudin, 1802) | LC | P | P | P | P | P |
| 12 | *Monilesaurus rouxii* (Duméril & Bibron, 1837) | LC | P | | | | |
| 13 | *Psammophilus blanfordanus* (Stoliczka, 1871) | LC | | P | | | |
| 14 | *Saara hardwickii* (Gray, 1827) | NE | | | | P | P |
| 15 | *Sitana spinaecephalus* Deepak et al., 2016 | LC | P | P | P | P | P |
| 16 | *Trapelus agilis* (Olivier, 1807) | NE | | | P | P | P |
| | **Family: Chamaeleonidae** | | | | | | |
| 17 | *Chamaeleo zeylanicus* Laurenti, 1768 | LC | P | P | P | P | P |
| | **Family: Gekkonidae** | | | | | | |
| 18 | *Cyrtodactylus deccanensis* (Günther, 1864) | LC | P | | | | |
| 19 | *Cyrtopodion kachhense* (Stoliczka, 1872) | NE | | | | P | P |
| 20 | *Cyrtopodion scabrum* (Heyden, 1827) | LC | | | P | P | P |
| 21 | *Cyrtopodion* sp. | | | P | | | |
| 22 | *Cyrtodactylus varadgirii* Agarwal et al., 2016 | NE | P | P | | P | |
| 23 | *Hemidactylus flaviviridis* Rüppell, 1835 | LC | P | P | P | P | P |
| 24 | *Hemidactylus frenatus* Duméril & Bibron, 1836 | LC | P | | | P | |
| 25 | *Hemidactylus* cf. *gleadowi* Murray, 1884 | NE | P | P | P | P | P |
| 26 | *Hemidactylus gracilis* Blanford, 1870 | LC | P | | | | |
| 27 | *Hemidactylus gujaratensis** Giri et al., 2009 | VU | | | | P | |
| 28 | *Hemidactylus leschenaultii* Duméril & Bibron, 1836 | LC | P | P | P | P | P |
| 29 | *Hemidactylus maculatus* Duméril & Bibron, 1836 | LC | P | | | | |
| 30 | *Hemidactylus murrayi* Gleadow, 1887 | NE | P | P | | P | |
| 31 | *Hemidactylus persicus* Anderson, 1872 | LC | | | P | | |

Table 1. Continued.

| Sr No | Species | IUCN status | SG | CG | NG | SAU | KU |
|---|---|---|---|---|---|---|---|
| 32 | *Hemidactylus robustus* Heyden, 1827 | NE | | | | P | |
| 33 | *Hemidactylus sahgali* Mirza et al., 2018 | LC | P | P | P | P | P |
| | **Family: Eublepharidae** | | | | | | |
| 34 | *Eublepharis fuscus* Börner, 1974 | LC | | | | P | P |
| | **Family: Lacertidae** | | | | | | |
| 35 | *Acanthodactylus cantoris* Günther,1864 | NE | | | P | P | P |
| 36 | *Ophisops beddomei* (Jerdon, 1870) | LC | P | P | | | |
| 37 | *Ophisops jerdonii* Blyth, 1853 | LC | | | P | P | P |
| 38 | *Ophisops kutchensis** Agarwal et al., 2018 | NE | | | | P | P |
| 39 | *Ophisops pushkarensis* Agarwal et al., 2018 | NE | | | P | | |
| | **Family: Scincidae** | | | | | | |
| 40 | *Ablepharus grayanus* (Stoliczka, 1872) | NE | | | P | | P |
| 41 | *Eurylepis taeniolatus* Blyth, 1854 | NE | | | P | | P |
| 42 | *Eutropis allapallensis* (Schmidt, 1926) | LC | P | P | | | |
| 43 | *Eutropis carinata* (Schneider, 1801) | LC | P | P | P | P | P |
| 44 | *Eutropis dissimilis* (Hallowell, 1857) | NE | | P | | | |
| 45 | *Eutropis macularia* (Blyth, 1853) | LC | P | P | P | P | P |
| 46 | *Lygosoma albopunctata*[#] (Gray, 1846) | LC | P | P | | | |
| 47 | *Lygosoma guentheri*[#] (Peters, 1879) | LC | P | P | P | | |
| 48 | *Lygosoma lineata*[#] (Gray, 1839) | LC | P | P | | P | |
| 49 | *Lygosoma punctata*[#] (Gmelin, 1799) | LC | P | P | P | P | |
| 50 | *Ophiomorus raithmai* Anderson & Leviton, 1966 | LC | | | | | P |
| | **Family: Varanidae** | | | | | | |
| 51 | *Varanus bengalensis* (Daudin, 1802) | LC | P | P | P | P | P |
| 52 | *Varanus griseus* (Daudin, 1803) | NE | | | | | P |
| | Snakes | | | | | | |
| | **Family: Acrochordidae** | | | | | | |
| 53 | *Acrochordus granulatus* (Schneider,1799) | NE | P | P | | P | P |
| | **Family: Uropeltidae** | | | | | | |
| 54 | *Uropeltis ellioti* (Gray, 1858) | LC | P | | | | |
| 55 | *Uropeltis macrolepis* (Peters, 1862) | LC | P | | | | |
| | **Family: Pythonidae** | | | | | | |
| 56 | *Python molurus* (Linnaeus, 1758) | LC | P | P | P | P | P |
| | **Family: Erycidae** | | | | | | |
| 57 | *Eryx conicus* (Schneider,1801) | LC | P | P | P | P | P |
| 58 | *Eryx johnii* (Russell,1801) | LC | P | P | P | P | P |
| | **Family: Colubridae** | | | | | | |
| 59 | *Ahaetulla nasuta* (Lacépède, 1789) | LC | P | P | | P | |
| 60 | *Amphiesma stolatum* (Linnaeus, 1758) | LC | P | P | P | P | |
| 61 | *Argyrogena fasciolata* (Shaw, 1802) | LC | P | P | P | P | |
| 62 | *Boiga beddomei* (Wall, 1909) | DD | P | | | | |
| 63 | *Boiga forsteni* (Duméril, Bibron & Duméril, 1854) | LC | P | P | P | P | |
| 64 | *Boiga trigonata* (Schneider, 1802) | LC | P | P | P | P | P |

Table 1. Continued.

| Sr No | Species | IUCN status | SG | CG | NG | SAU | KU |
|---|---|---|---|---|---|---|---|
| 65 | *Chrysopelea ornata* (Shaw, 1802) | LC | P | | | | |
| 66 | *Coelognathus helena* (Daudin, 1803) | LC | P | P | P | P | P |
| 67 | *Dendrelaphis tristis* (Daudin, 1803) | LC | P | P | | P | |
| 68 | *Elachistodon westermanni* Reinhardt, 1863 | LC | P | P | P | P | |
| 69 | *Fowlea piscator* (Schneider, 1799) | LC | P | P | P | P | P |
| 70 | *Lycodon aulicus* (Linnaeus, 1758) | LC | P | P | P | P | P |
| 71 | *Lycodon flavomaculatus* Wall, 1907 | LC | P | P | | P | |
| 72 | *Lycodon striatus* (Shaw, 1802) | LC | P | P | P | P | P |
| 73 | *Oligodon arnensis* (Shaw, 1802) | LC | P | P | P | P | P |
| 74 | *Oligodon taeniolatus* (Jerdon, 1853) | LC | P | P | P | P | P |
| 75 | *Platyceps gracilis* (Günther, 1862) | NE | P | P | P | | |
| 76 | *Platyceps ventromaculatus* (Gray, 1834) | LC | P | P | P | P | P |
| 77 | *Ptyas mucosa* (Linnaeus, 1758) | LC | P | P | P | P | P |
| 78 | *Rhabdophis plumbicolor* (Cantor, 1839) | LC | P | P | P | | |
| 79 | *Sibynophis subpunctatus* (Duméril, Bibron & Duméril, 1854) | LC | P | P | | P | |
| 80 | *Spalerosophis atriceps* (Fischer, 1885) | NE | | | P | | P |
| 81 | *Wallophis brachyura* (Günther, 1866) | LC | P | P | | | |
| 82 | *Wallaceophis gujaratensis* * Mirza et al. 2016 | NE | | P | | P | |
| | **Family: Lamprophiidae** | | | | | | |
| 83 | *Psammophis leithii* Günther, 1869 | LC | P | P | P | P | P |
| 84 | *Psammophis longifrons* Boulenger, 1890 | DD | P | P | | | |
| | **Family: Elapidae** | | | | | | |
| 85 | *Bungarus caeruleus* (Schneider, 1801) | LC | P | P | P | P | P |
| 86 | *Bungarus sindanus* Boulenger, 1897 | NE | | | | P | P |
| 87 | *Calliophis melanurus* (Shaw, 1802) | LC | P | P | | P | |
| 88 | *Calliophis nigrescens* (Günther, 1862) | LC | P | | | | |
| 89 | *Hydrophis caerulescens* (Shaw, 1802) | LC | P | P | | P | |
| 90 | *Hydrophis cantoris* Günther, 1864 | DD | | | | P | |
| 91 | *Hydrophis curtus* (Shaw, 1802) | LC | P | P | | P | |
| 92 | *Hydrophis cyanocinctus* Daudin, 1803 | LC | P | P | | P | P |
| 93 | *Hydrophis gracilis* (Shaw, 1802) | LC | | | | P | |
| 94 | *Hydrophis mamillaris* (Daudin, 1803) | DD | | | | P | |
| 95 | *Hydrophis platurus* (Linnaeus, 1766) | LC | P | P | | P | P |
| 96 | *Hydrophis schistosus* Daudin, 1803 | LC | P | P | | | |
| 97 | *Hydrophis spiralis* (Shaw, 1802) | LC | | | | P | |
| 98 | *Naja naja* (Linnaeus, 1758) | LC | P | P | P | P | P |
| | **Family: Homalopsidae** | | | | | | |
| 99 | *Cerberus rynchops* (Schneider, 1799) | LC | P | P | | P | |
| 100 | *Gerarda prevostiana* (Eydoux & Gervais, 1837) | LC | P | P | | P | |
| | **Family: Viperidae** | | | | | | |
| 101 | *Daboia russelii* (Shaw & Nodder, 1797) | LC | P | P | P | P | |
| 102 | *Echis carinatus* (Schneider, 1801) | LC | P | P | P | P | P |

Table 1. Continued.

| Sr No | Species | IUCN status | SG | CG | NG | SAU | KU |
|---|---|---|---|---|---|---|---|
| 103 | *Trimeresurus gramineus* (Shaw, 1802) | LC | P | P | | | |
| | **Family: Typhlopidae** | | | | | | |
| 104 | *Indotyphlops braminus* (Daudin, 1803) | LC | P | P | P | P | P |
| 105 | *Indotyphlops porrectus* (Stoliczka, 1871) | NE | | | | P | |
| 106 | *Grypotyphlops acutus* (Duméril & Bibron, 1844) | LC | P | P | | P | |
| | **Crocodiles** | | | | | | |
| | **Family: Crocodylidae** | | | | | | |
| 107 | *Crocodylus palustris* (Lesson, 1831) | VU | P | P | P | P | P |

# These species have now been transferred to genus *Riopa* Gray, 1839 following the recent phylogeny of snake skinks by Freitas et al., 2019.

**References**


Acharya, H. (1949): List of reptiles of Gujarat state. Prakruti **8**: 156–178.

Agarwal, I., Bauer, A.M., Jackman, T.R., Karanth, P. (2014): Cryptic species and Miocene diversification of Palaearctic naked-toed geckos (Squamata: Gekkonidae) in the Indian dry zone. Zoologica Scripta **43**: 455–471.

Agarwal, I., Khandekar, A., Ramakrishnan, U., Vyas, R., Giri, V.B. (2018): Two new species of the *Ophisops microlepis* (Squamata: Lacertidae) complex from northwestern India with a key to Indian *Ophisops*. Journal of Natural History **52**: 819–847.

Akhtar, A.S., Tiwari, J.K. (1991): Extension of the range of the black cobra *Naja naja oxiana*. Journal of the Bombay Natural History Society **88**: 123.

Auffenberg, W., Rehman, H., Mat, F., Perveen, Z. (1989): A study of *Varanus flavescens* (Hardwicke & Gray) (Sauria: Varanidae). Journal of the Bombay Natural History Society **86**: 286–307.

Bhatt, K. (1989): New locality record for the Indian pink ringed terrapin. Journal of the Bombay Natural History Society **86**: 253.

Buch, S.M. (1999): A flying snake (*Chrysopelea ornata*) in a rural area near Rajkot city (Gujarat). Cobra **35–36**: 33.

Champion, H.G., Seth, S.K. (1968): A Revised Survey of the Forest Types of India. New Delhi, India, Government of India.

Daniel, J.C., Shull, E.M. (1963): A list of reptiles and amphibians of Surat, Dangs, South Gujarat. Journal of the Bombay Natural History Society **60**: 737–743.

Datta-Roy, A., Singh, M., Karanth, K.P. (2014): Phylogeny of endemic skinks of the genus *Lygosoma* (Squamata: Scincidae) from India suggests an in situ radiation. Journal of Genetics **93**: 163–167.

Deepak, V., Giri, V.B., Asif, M., Dutta, S.K., Vyas, R., Zambre, A.M., Bhosale, H., Karanth, P.K. (2016): Systematics and phylogeny of *Sitana* (Reptilia: Agamidae) of Peninsular India, with the description of one new genus and five new species. Contributions to Zoology **85**: 67–111.

Frazier, J., Das, I. (1994): Some notable records of testudines from the Indian and Burmese sub-regions. Hamadryad **19**: 47–66.

Freitas, E.S., Datta-Roy, A., Karanth, P., Grismer, L.L., Siler C.D. (2019): Multilocus phylogeny and a new classification for African, Asian and Indian supple and writhing skinks (Scincidae: Lygosominae). Zoological Journal of the Linnean Society **186**. In press.

FSI (Forest Survey of India) (2017): India State of Forest Report. Available at: http://fsi.nic.in/fsi-node. Accessed on 15 May 2018.

Gayen, N.C. (1999): A synopsis of the reptiles of Gujarat, western India. Hamadryad **24**: 1–22.

Giri, V.B., Bauer, A.M., Vyas, R., Patil, S. (2009): New species of rock-dwelling *Hemidactylus* (Squamata: Gekkonidae) from Gujarat, India. Journal of Herpetology **43**: 385–393.

Gleadow, F. (1887): Description of a new lizard from the Dangs. Journal of the Bombay Natural History Society **2**: 49–51.

IUCN (International Union for the Conservation of Nature) (2018): IUCN Red List of Threatened Species. Version 3. Available at: http//www.iucnredlist.org. Accessed on 15 May 2018.

Joshi, P., Misher, C., Thorat, O. (2017): New record of agamid lizard *Trapelus agilis* (Olivier, 1804) (Squamata: Agamidae) from Gujarat, India. Russian Journal of Herpetology **24**: 78–80.

Kapadia, G.A. (1951): Animal List of Mahagujarat. Bombay, India, Gujarat Research Society. 18 pp.

Kumar, S. (2009): Fauna of Nal Sarovar, Gujarat. Wetland Ecosystem Series, No. 11. Kolkata, India, Zoological Survey of India.

Lajmi, A., Giri, V.B., Karanth, K.P. (2016): Molecular data in conjunction with morphology help resolve the *Hemidactylus brookii* complex (Squamata: Gekkonidae). Organism Diversity and Evolution **16**: 659–677.

McCann, C. (1938): The reptiles and amphibia of Cutch. Journal of the Bombay Natural History Society **40**: 425–427.

Mirza, Z.A., Patel, H. (2018): Back from the dead! Resurrection and revalidation of the Indian endemic snake genus *Wallophis* Werner, 1929 (Squamata: Colubridae) insights from molecular data. Mitochondrial DNA Part A **28**: 331–334.

Mirza, Z.A., Vyas, R., Patel, H., Maheta, J., Sanap, R.V. (2016): A new Miocene-divergent lineage of Old World racer snake from India. PLoS One **11**: e0148380.

Mirza, Z.A., Gowande, G.G., Patil, R., Ambekar, M., Patel, H. (2018): First appearance deceives many: disentangling the *Hemidactylus triedrus* species complex using an integrated approach. PeerJ **6**: e5341.

Mohan, A., Visvanathan, A.C., Vasudevan, K. (2018): Phylogeny and conservation status of the Indian egg-eater snake, *Elachistodon westermanni* Reinhardt, 1863 (Serpentes, Colubridae). Amphibia-Reptilia **39**: 317–324.

Mohapatra, P.P, Schulz, K.D., Helfenberger, N., Hofmann, S., Dutta, S.K. (2016): A contribution to the Indian trinket snake, *Coelognathus helena* (Daudin, 1803), with the description of a new subspecies. Russian Journal of Herpetology **23**: 115–144.

Munjpura, S. (2014): Will the exotic Red-eared Slider *Trachemys scripta elegans* become invasive in India? Jalaplavit **5**: 47–48.

Murray, J.A. (1886): The Reptiles of Sind. Bombay, India, The Education Society's Press.

Naik, Y.M., Vinod, K.R., Pradeep, P.K. (1993): Reptiles of Narmada valley, Gujarat. Cobra **11**: 7–8.

Naoroji, R.K., Monga, S.G. (1983): Observations on the Crested Serpent Eagle (*Spilornis cheela*) in Rajpipla forests, South Gujarat. Journal of the Bombay Natural History Society **80**: 273–285.

Patel, H., Naik, V., Tank, S.K. (2016): The Common House Gecko, *Hemidactylus frenatus* Schlegel in Dumeril & Bibron 1836 (Reptilia: Gekkonidae) in Gujarat, India. IRCF Reptiles & Amphibians **23**: 178–182.

Patel, H., Vyas, R., Naik, V., Dudhatra, B., Tank, S.K. (2018): Herpetofauna of the Northern Western Ghats of Gujarat, India. Zoology & Ecology **23**: 213-223.

Patel, H., Vyas, R., Tank, S.K. (2015): On the distribution, taxonomy and natural history of the Indian Smooth Snake, *Coronella brachyura* (Günther, 1866). Amphibian & Reptile Conservation **9**: 120–125.

Patel, J.D., Reddy, A.S. (1995): Flora, fauna and EM of SSP-command between Narmada and Sabarmati River. Vallabh Vidhya Nagar, India, VVN, SP University.

Purkayastha, J., Kalita, J., Brahma, R.K., Doley, R., Das, M. (2018): A review of the relationships of *Xenochrophis cerasogaster* Cantor, 1839 (Serpentes: Colubridae) to its congeners. Zootaxa **4514**: 126–136.

Rodgers, W.A., Panwar, H.S., Mathur, V.B. (2002): Wildlife Protected Area Network. In: India: a Review (Executive Summary). Dehradun, India, Wildlife Institute of India.

Sharma, R.C. (1982): Taxonomic and ecological studies on the reptiles of Gujarat. Records of the Zoological Survey of India **80**: 85–106.

Sharma, R.C. (2000): Reptilia. In: Fauna of Gujarat (Part 1). Vertebrates, p. 243–298. Alfred, J.R.B., Ed., Kolkata, India, Zoological Survey of India.

Sharma, R.C. (2007): The Fauna of India and Adjacent Countries. Reptilia. Volume III (Serpentes). Kolkata, India, Zoological Survey of India.

Sharma, V., Jani, M. (2015): Natural history notes. *Lycodon travancoricus*. Distribution. Herpetological Review **46**: 574.

Smith, M.A. (1931): The Fauna of British India, Including Ceylon and Burma. Volume I. Loricata, Testudines. London, United Kingdom, Taylor and Francis.

Smith, M.A. (1935): The Fauna of British India, Including Ceylon and Burma. Reptilia and Amphibia. Volume II. Sauria. London, United Kingdom, Taylor and Francis.

Smith, M.A. (1943): The Fauna of British India, Ceylon and Burma, Including the Whole of the Indo-Chinese Sub-Region. Reptilia and Amphibia. Volume III. Serpentes. London, United Kingdom, Taylor and Francis.

Stoliczka, F. (1872): Notes on the reptilian and amphibian fauna of Kachh. Proceedings of the Asiatic Society of Bengal **1872**: 71–85.

Takeuchi, H., Savitzky, A.H., Ding, L., De Silva, A., Das, I., Nguyen, T.T., et al. (2018): Evolution of nuchal glands, unusual defensive organs of Asian natricine snakes (Serpentes: Colubridae), inferred from a molecular phylogeny. Ecology and Evolution **8**: 10219–10232.

Uetz, P., Freed, P., Hošek, J. (2018): The Reptile Database. Available at http://www.reptile-database.org. Accessed on 30 November 2018.

Vyas, R. (1988): Notes on snakes from district Dang, Gujarat state. Journal of the Bombay Natural History Society **85**: 200.

Vyas, R. (1993): Studies on Some Snakes (Ophidia-Reptilia) of Gujarat State, India. Unpublished PhD Thesis, Bhavnagar University, Bhavnagar, India.

Vyas, R. (1998): The reptiles of Gujarat State: updated distribution. Tigerpaper **25**: 8–14.

Vyas, R. (2000a): A review of reptile studies in Gujarat state. Zoos' Print Journal **15**: 386–390.

Vyas, R. (2000b): First record of *Psammophilus blanfordanus* (Stolickza, 1871) (Family: Agamidae) from Gujarat, India. Journal of the Bombay Natural History Society **97**: 432–434.

Vyas, R. (2003). First record of *Ophisops beddomei* (Jerdon, 1870) from Gujarat State, western India. Hamadryad **27**: 280–281.

Vyas, R. (2004a): First record of *Mabuya allapallensis* from Gujarat State, India. Hamadryad **28**: 136–138.

Vyas, R. (2004b): Herpetofauna of Vansda National Park, Gujarat. Zoos' Print Journal **19**: 1512–1514.

Vyas, R. (2005): First record of Asian house gecko *Hemidactylus frenatus* (Schlegel) from Gujarat State, western India. Cobra **60**: 13–17.

Vyas, R. (2007): Present conservation scenario of Reptile fauna in Gujarat state, India. Indian Forester **133**: 1381–1394.

Vyas, R. (2015). Status of Ganges Soft-shell Turtle *Nilssonia gangetica* amidst deplorable scenarios in urban wetlands of Central Gujarat State, India. Reptile Rap **17**: 3–12.

Vyas, R. (2017): A Northern River Terrapin (*Batagur baska*) from Kutch, with comments on the species distribution in western India and Pakistan. IRCF Reptiles & Amphibians **24**: 128–131.

Vyas, R., Desai, S.R. (2010): The record of Beddome's Cat Snake *Boiga beddomei* from Purna Wildlife Sanctuary, Gujarat State, India. Reptile Rap **10**: 10–13.

Vyas, R., Patel, B.H. (1990): A survey of fresh water turtles of Gujarat. Journal of the Bombay Natural History Society **87**: 152–155.

Vyas, R., Patel, H. (2013): Notes on the distribution and natural history of *Psammophis longifrons* Boulenger, 1896 (Serpents [sic]: Psammophidae: Psammophinae) in Gujarat, India. Russian Journal of Herpetology **20**: 217–222**.**

Vyas, R., Patel, S.S. (2007): New distributional records of the endemic snake *Coronella brachyura* (Günther 1866) (Serpentes, Colubridae, Colubrinae) from Gujarat State, India. Sauria **29**: 47–50.

Vyas, R., Prajapati, V. (2012): Record of *Geckoella deccanensis* (Günther, 1864) (Squamata: Gekkonidae) from Dang, Gujarat State, India. Gekko **6**: 2–6.

Vyas, R., Upadhyay, K. (2008): On the occurrence of *Lycodon flavomaculatus* Wall, 1907 in Gujarat State, India. Sauria **30**: 55–58.

Vyas, R., Giri, V., Bauer, A.M. (2006): First record of *Hemidactylus persicus* Anderson, 1872 (Squamata: Sauria: Gekkonidae) from the Republic of India, with notes on its distribution. Hamadryad **30**: 209–211.

Vyas, R., Patel, H., Dudhatra, B. (2017): The Indian Egg-Eating Snake, *Elachistodon westermanni* (Colubridae): comments on distribution and new localities from Gujarat, India. IRCF Reptiles & Amphibians **24**: 203–206.

Vyas, R., Patel, V.V., Thakur, M.N. (2011): Records of the Slender Racer, *Coluber gracilis* (Günther, 1862), from Gujarat State with Notes on its Distribution. Sauria **33**: 51–56.

Wall, F. (1924): The hamadryad or king cobra, *Naia hannah* (Cantor). Journal of the Bombay Natural History Society **30**: 189–195.

Wallach, V., Williams, K.L., Boundy, J. (2014): Snakes of the World, a Catalogue of Living and Extinct Species. Boca Raton, Florida, USA. CRC Press.

Whitaker, R., Captain, A. (2004): Snakes of India, the Field Guide. Chennai, India. Draco Books.

Yadav, O., Yankanchi, S. (2015): Occurrence of *Ophiophagus hannah* Cantor, 1836 (Squamata, Elapidae) in Tillari, Maharashtra, India. Herpetology Notes **8**: 493–494.

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# 7 Studying Chiropterans: How to make a beginning!!

**Introduction**

Bats are mammals belong to the order *Chiroptera*, meaning 'hand-wing'. *Chiroptera* has two suborders, *Megachiroptera* and *Microchiroptera* with 17 families and 177 genera making it to almost 1400 species worldwide. Bats belonging to the suborder ***Microchiroptera*** are the microbats or insect-eating bats. The ***Megachiroptera*** consists of the megabats or fruit-eating bats. India is home to about a hundred species of bats, including 12 fruit bats, such as the fulvous fruit bat *Rousettusleschenaulti*, Indian flying fox *Pteropusgiganteus*, Nicobar flying fox *P faunulus*, island flying fox *P hypomelanus*, Blyth's flying fox *P melanotus*, short-nosed fruit bat *Cynopterus sphinx*, lesser dog-faced fruit bat *C brachyotis*, Ratanaworabhan's fruit bat *Megaeropsniphanae*, Salim Ali's fruit bat *Latidenssalimalii*, Blanford's fruit bat *Sphaeriasblanfordi*, dawn bat *Eonycterisspelaea*, and hill long-tongued fruit bat *Macroglossussobrinus*. Whether solitary or colonial; each species gives birth to its young and an elaborate parental care is seen in bats. Sadly, though, data on the conservation status, population density, and ecology of many of these species is limited due to lack of field studies.

Other than taxonomical classification bats are also grouped according to its feeding preferences. Such as:

1. **Frugivorous bats**: Frugivorous bats feeds on fruits, flowers andor flower products. They play an important role in pollination and speed dispersal of many plants in various parts of the world. These bats have large, keen eyes, an acute sense of smell and small ears as compared to the size of their bodies. In general, these bats do not produce ultrasound; however, those belonging to the genus *Rousettus* have a primitive echolocation system. They make an audible clicking sound through their mouths.
2. **Insectivorous bats:** Most microchiropteran bats feeds on insects and other arthropods. They have small eyes and large ears, and produce ultrasound over 15 kHz, which human ears are unable to catch. They rely on echolocation for navigation and to catch insects. The insectivorous bats are further divided into two groups:
   a) **Sheath-tailed bat**, also called sac-winged bat, any of about 50 bat species named for the way in which the tail protrudes from a sheath in the membrane attached to the hind legs. Bats belonging to genus *Taphozous* sp. (Tomb bats) such as Naked-rumped tomb bat (*Taphozousnudiventris*), Long-winged tomb bat (*Taphozouslongimanus),* Black-bearded tomb bat (*Taphozousmelanopogon*), *Pipistrelle sp.*, etc.

b) **Free-tailed bat**, also called **mastiff bat**, any of 100 species of bats, so called for the way in which part of the tail extends somewhat beyond the membrane connecting the hind legs. Some free-tailed bats are also known as mastiff bats because their faces bear a superficial resemblance to those dogs. Free-tailed bats eat insects and roost in tree hollows, caves, and buildings. They are found worldwide in warm regions. Most species live in groups, and some form colonies with populations numbering in the millions, such as the colonies of Greater Mouse tailed Bats (*Rhinopomamicrophyllum)* and Lesser Mouse tailed bats (*Rhinopomahardwickii)* in mines of Jambughoda Wildlife Sanctuary, Gujarat.

3. **Insectivorous/Predacious bats:** Few species of bats such as Greater False Vampire bat (*Megaderma lyra lyra),* Lesser False Vampire bat *(Megadermaspasma)* and Leaf nosed bats *(Hipposideros sp.)*are opportunistic feeders and have heterogeneous diet feeding not only insects but also on small rodents, shrews, small lizards, fishes along with other bats.

**Ecosystem services and conservation status of bats**

Bats help maintain healthy ecosystems and are important pieces of the puzzle for our natural spaces, including national parks. Tropical fruit bats play a significant role in rainforest ecosystems. Pollination of flowers, dispersal of seeds of trees, shrubs and climbers are all part of their function in the ecosystem. Besides, bat droppings in the caves they occupy support a delicate ecosystem composed of unusual organisms. The Indian Wildlife Protection Act of 1972 consigned bats to schedule V as 'vermin'. While the more glamorous animals -- elephants, rhinos, lions and tigers -- have received considerable attention from conservationists in the country, bats have been largely ignored in such discourses.As for the Wildlife Act, it names just two bat species for protection — Salim Ali's fruit bat and Wroughton's free-tailed bat. Along with this, threats like habitat loss, wind energy turbines, and white-nose syndrome, pose a significant threat to an already declining bat population worldwide. More recently, the source of Sars-covid19 virus is alleged to be the horse shoe bats in Wuhan province of China. Such studies are inconclusive and often put anthropogenic pressure on a single species.

**Methods for Catching and Studying Bats**

Bats are small animals that can be hard to find. They are often well-hidden in trees or deep inside caves and only come out at night to hunt for insects. This makes bats difficult to study, so special techniques have been developed for studying and counting bats.

**Mist nets** –Mist netting is one of the most common and effective technique of capturing bats. This loose mesh is practically invisible when strung up between two poles at dusk, and bats get caught in it when they fly by. Researchers can then carefully free the bat and collect information, such as the type of species or weight, collect samples for genetic studies or disease surveillance, or mark the bat with a band or other device so it can be tracked. The bat is then released to continue its nightly activities. Bats are quick learners, so forest staff and researchers have to be creative about where to set up the nets.

Fig1. Bat trapped in a mist-net

**Acoustic surveys** - Scientists can record the **echolocations** or calls that bats make when they are flying through the air using specialized microphones and recording devices. Just like birds, different species of bats tend to make different types of sounds, which allows the researcher to identify the species of bat that flew by. The recording device may be left in the field to record bat calls over a number of nights or can be used to survey an area in one night by walking or driving along a specific route. Additionally, many parks have permanent monitoring stations to track bat activity year-round.

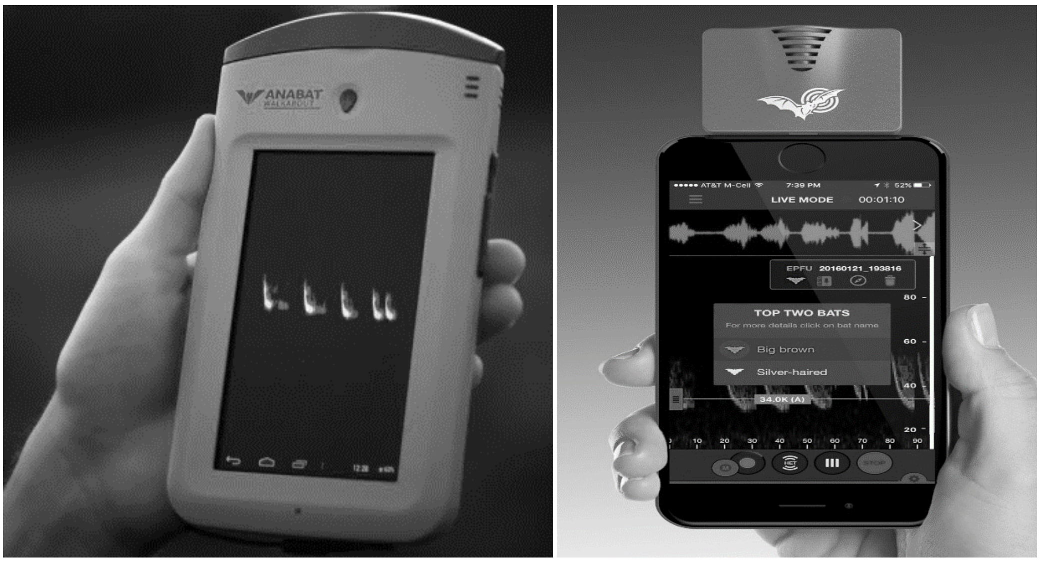



Fig 2. Bat Detectors

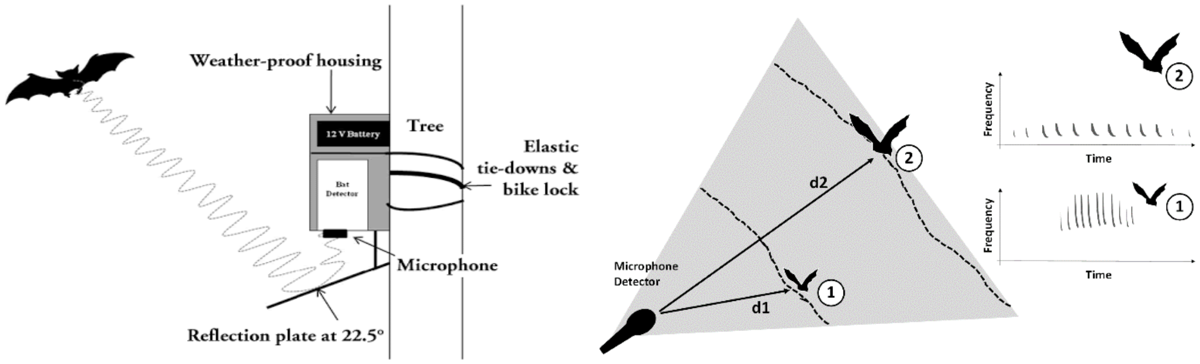



Fig 3. How does a bat detector work.

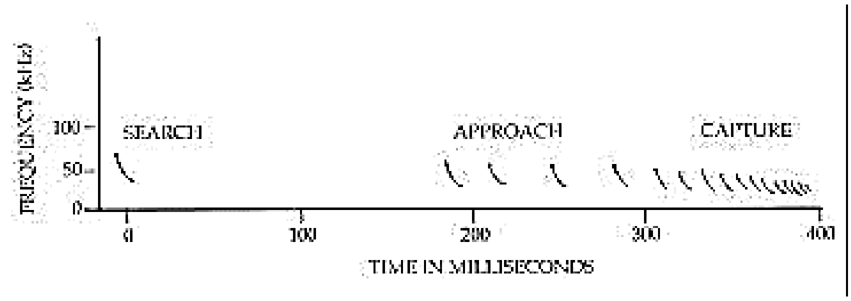



Fig 4. Software data of Bat calls during feeding

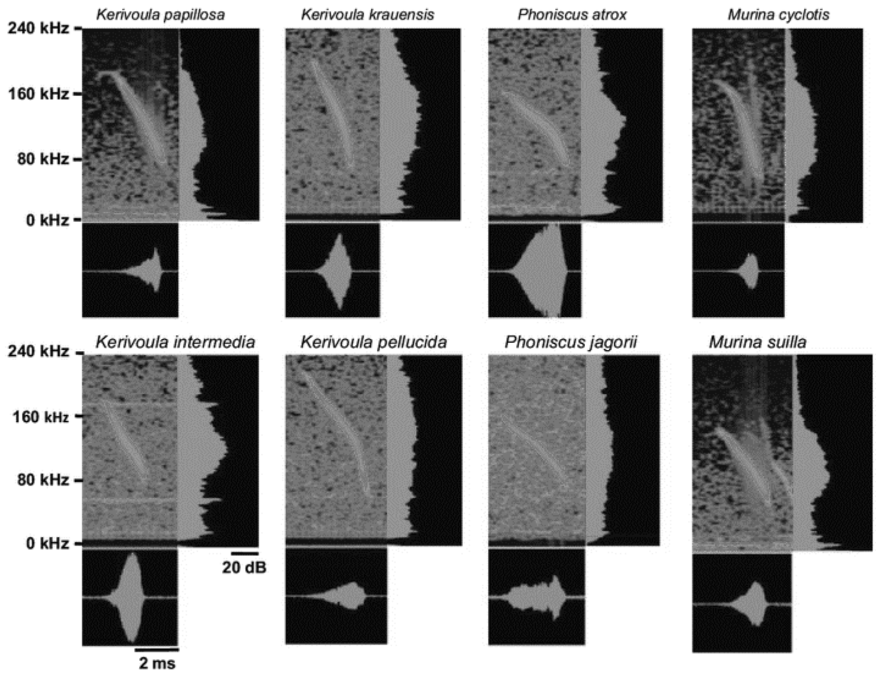



Fig 5. Species specific call signatures of bats

**Field surveys** - In a field survey, scientists visit locations where bats are likely to live - caves, trees, crevices, abandoned mines, etc. They are often looking for numbers and species of bats that are at these locations at different times of the year. Some special tools, like infrared cameras, slow motion cameras or tele lenses, can be helpful for finding and counting bats. It is very difficult to identify bats in flight like we do with the birds. Hence, photography of its facial features (from different angles), patagium, body, hind parts, etc can provide clues for their identification. However, capture and records of their character matrix remain the gold standard for their identification.

**Radio transmitters** - In some cases, researchers need to be able to track a bat to learn about the elusive places that bats go to rest, hibernate or raise young. The information helps us know where bats are during different times of the year and what locations they need to protect for the bats. Temporary radio transmitters are fitted on the back of a bat (like a tiny backpack) after it is captured using a net or other method. The bat is then released. Throughout the next few weeks, the researchers can track its movements using an antenna to detect the signal that is constantly sent out from the tiny radio transmitter on the bat. After a few weeks, the transmitter falls off and the bat can return to its secretive ways.

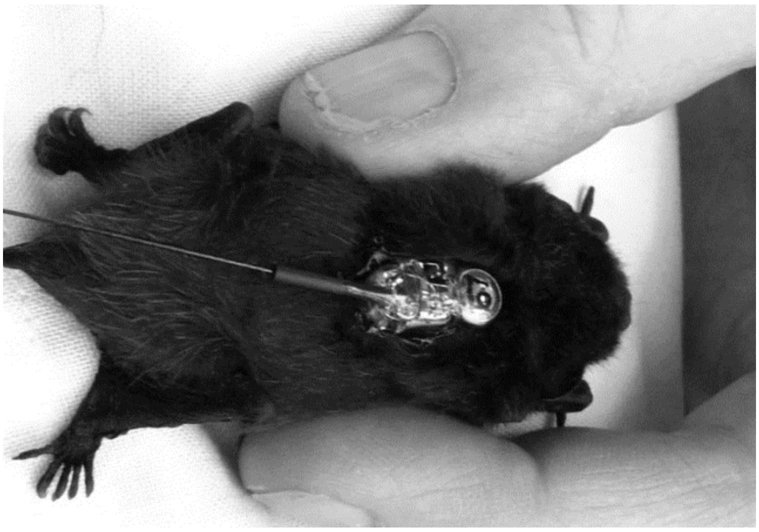
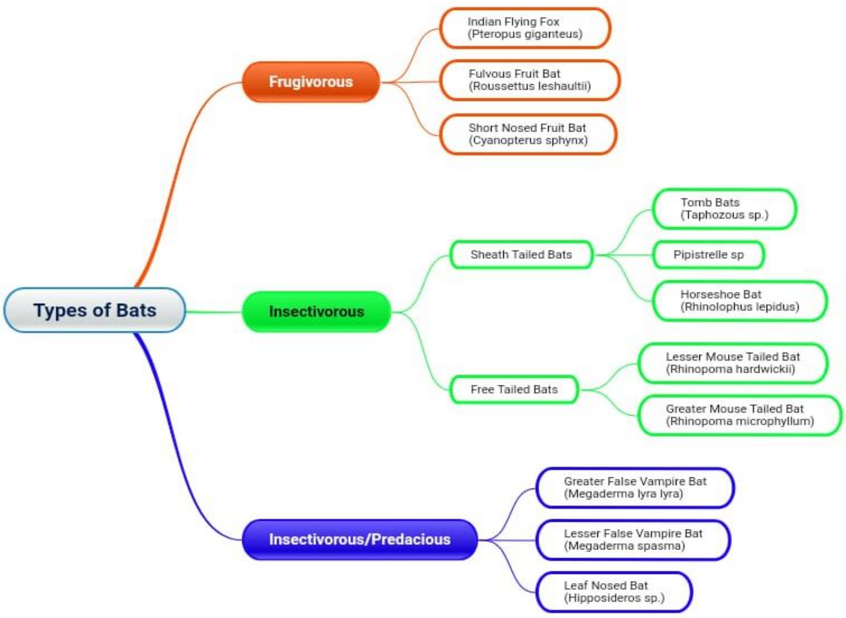
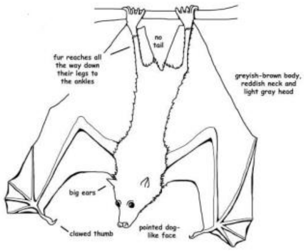
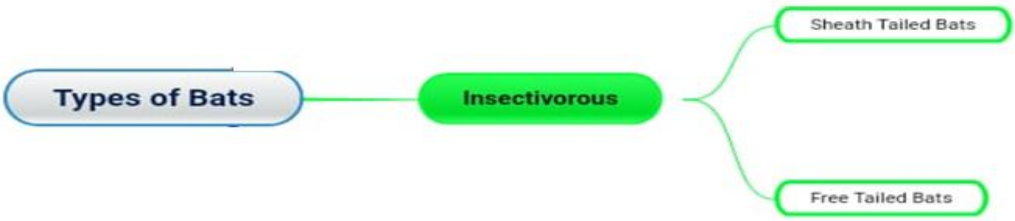


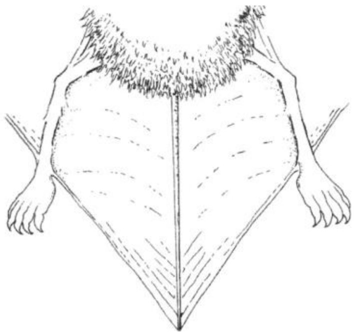
Fig 6. Radio-transmitter tagging on bats



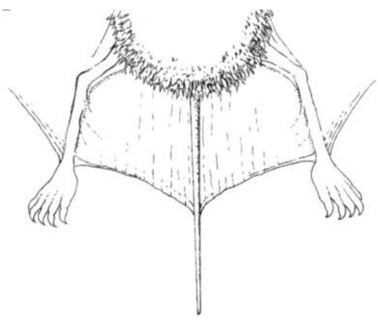




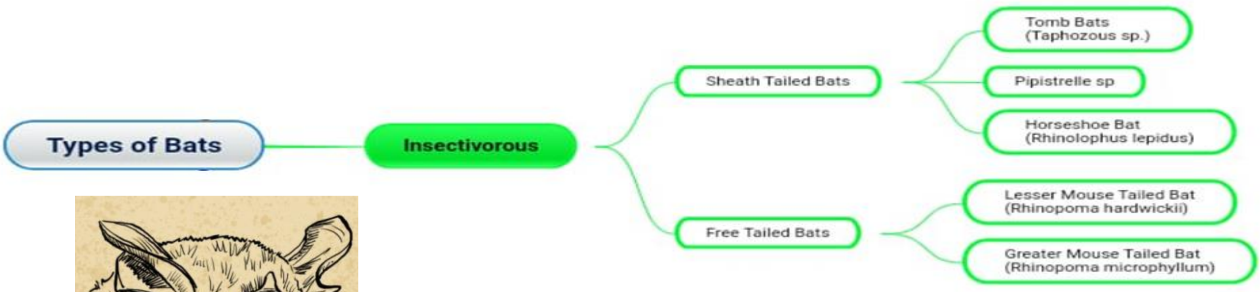



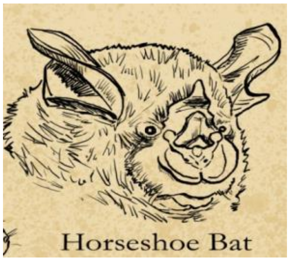



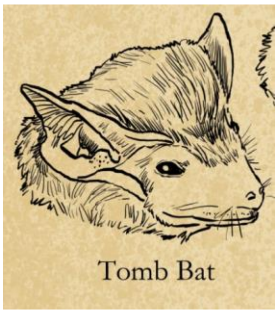
Sheath Tailed Bat

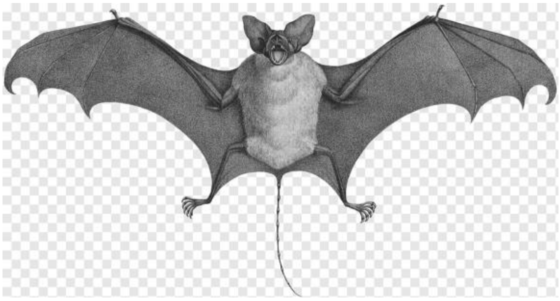


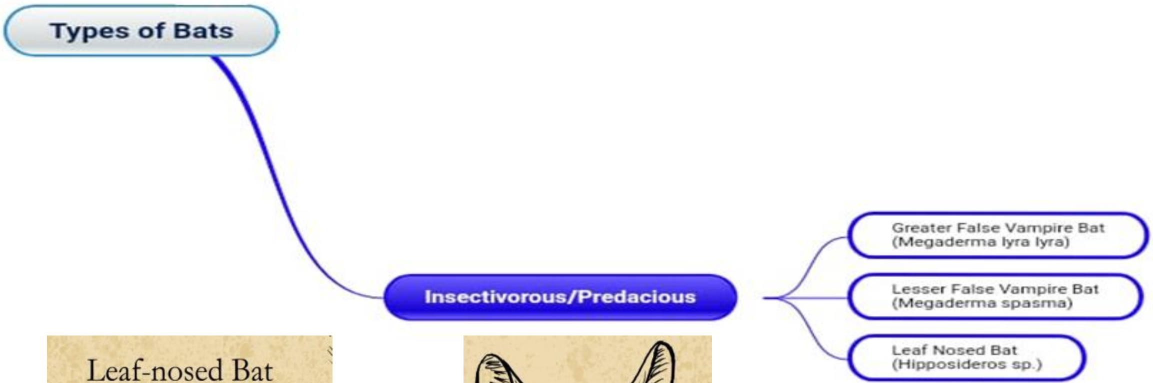
Free Tailed Bat

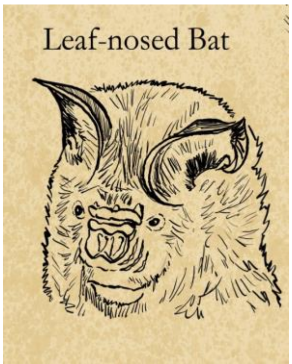

Types of Bats
Insectivorous
Sheath Tailed Bats
Free Tailed Bats
Tomb Bats (Taphozous sp.)
Pipistrelle sp
Horseshoe Bat (Rhinolophus lepidus)
Lesser Mouse Tailed Bat (Rhinopoma hardwickii)
Greater Mouse Tailed Bat (Rhinopoma microphyllum)


Horseshoe Bat


Tomb Bat




Types of Bats
Insectivorous/Predacious
Greater False Vampire Bat (Megaderma lyra lyra)
Lesser False Vampire Bat (Megaderma spasma)
Leaf Nosed Bat (Hipposideros sp.)


Leaf-nosed Bat


False Vampire

**Conservation status and challenges**

Bat species in India are delicately balanced on the survival scale. Attitudes towards bats, myths about them, reckless hunting, disturbance of their natural habitat and lack of legal protection are all prodding bats away from a true chance at survival. A few simple steps could change this trend. First, educate people about bats. We could tell others about the role of bats in the ecosystem, dispel myths about them and fear of them, and speak of the importance of bats for biodiversity. Secondly, we could plan bat conservation projects, and try to build bat roosting sites in our area. There is so little known about the population status of so many species of bats that one could start a local 'bat-watching' society. Thirdly, we could write to our local legislators and parliamentarians and demand legal protection for bats. The Wildlife Protection Act of India evidently needs revision to include protection to all species of fruit bats, and other selected insectivorous bats.

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# 8 Monitoring Methods for large mammals

Mammals are found in almost all the continents of the world and classified into 26 orders (Nowak 1991) and occupies all kinds of habitats from terrestrial to marine. Mammalian species are at risk from several factors, above all, the fast growing human population and rapid development are the most severe factor that directly affects the mammalian diversity. The conservation of mammals will require an ongoing and intensive effort aided with systematic and scientific approach, which is known as monitoring. Monitoring is very much necessary to identify the threatened species of mammals in different regions and to decide the hot-spots and priority species for conservation.

Proper study design is important to ensure the repeatability, reliability and compatibility of results for future investigators across the different geographic regions. For successful conservation of biological diversity, an investigator should know the number of species present in the area and the status and population viability of each species. For a scientific and systematic survey of mammals, the following steps should be included in research and monitoring design.

- Design of sample survey
- Selection of sampling units
- Determining sample size
- Stratification of the area
- Observability
- Sampling variability
- Standardization

Apart from above, some associated data is also very important during the survey, these associated data are:

- Climate and Environment
    - Basic weather data : Temperature, Precipitation
- Additional Environmental data
    - Wind speed and direction
    - Humidity, Pressure
    - moisture and water level
- Geographic characterization
- Habitat and micro-habitat

## Conducting a mammalian survey

Before conducting any biological survey, define the clear objective, that will help in planning and execution of the survey. This will also enhances the efficiency of data collection and improves the quality of the survey.

Before starting the survey, also consider the following:

1. Species list
2. Selection of target species
3. Previous study and literature on the species
4. Physical characteristics and behaviour of the species
5. Size of the area of interest (AoI)
6. Habitat and climate of AoI
7. Map of the study area
8. Choose the sample points/ plots

Mammals can be studied by direct detections by sightings, smell or sound and indirect detection by some equipment such as camera traps, recorders, and ultrasonic detectors. All these techniques are called observational techniques mostly used for diurnal or some time nocturnal mammals. Observational techniques are can be used to survey almost all the mammalian species. Using these technique generally we are able to study the density and relative abundance and total counts /sample counts. Following methods are popular and widely used for observational surveys.

**Silent detection for total counts**

*individual identification*
*observation of emergence from burrows or dens*
*total counts from mobile platforms*

**Silent detection for sample count**

*Line transects*
*Strip transects*
*Road counts*
*Quadrate sampling*

**Special techniques**

*Arial survey*
*Call playbacks*
*Night surveys*

**Mammalian Sign**

Even the most secretive mammals leave a record of their presence in different ways in the environment. The identification of these signs requires perceptiveness, good field experience and serendipity. Sign is an indicator of the presence of a given species and that species must have been identified in the act of producing the sign. Some typical mammalian signs can be used in mammalian inventory and monitoring programme because they are comparatively easy, less expensive and sometime more effective and rapid.

Learning of identification, interpretation and recording signs of mammals in the field can provide information about their habits, habitat use pattern, status and abundance that is very easy to study. Signs are the best determination to confirm the presence of a species in the area (Wilson et al., 1996). The signs of mammals in the field have varied age according to the time of decay or disappearance due to several factors. Using the sign age, we can also study the status and frequency of habitat use by a species in the area. Some most common and visually detectable signs are as follows; however one need a long field experience to identify the signs of mammals in different habitat types as they differ according to habitat, forest type, soil texture and other factors.

**Visually detected signs**

*Tracks: can tell about behaviour, size, age, sex, social status, etc.*

*Scats: used to know the status, food composition, determine population (deers and antelopes), disease, parasites, etc.*

*Stored food and food remains: can tell predator, prey, presence of scavengers etc.*

*Marks: (claw mark, scratch mark, scent mark, etc): Habitat use, territorial behaviour, etc.*

*Olfactory signs: Specific secretion, odor, social and anti- predator function also used in studying territorial behaviour of carnivores*

*Camera Traps: population status, estimation, habitat use, home ranges, etc.*

**Sign Age estimation for large mammals based on their decay range**

| Sign category | Subtype of sign | Decay range |
|---|---|---|
| Logs | rotten logs | 1 mo-1 yr |
| | firm dead wood | 3 mo-2 yrs |
| Termite nests | dug up-but not broken | 3 yrs |
| | partially destroyed | 2 yrs |
| | entirely destroyed | 1 yr |
| Soil digs | small | 1 mo-1 yr |
| | large | 3 mo-1 yr |
| Claw marks | - | 6 mo-8+ yrs |
| Stingless bee nests | under tree bases | 6 mo- 2 yrs |
| | cavity chewed in stem | 3 yrs-13+ yrs |
| Bite marks | small | 6 mo-8+ yrs |
| | large | 2 yrs |
| Scats | termites | 12-36 hours |
| | figs | 6-17 days |
| | various hard seeds | 6-43 days |
| Seedling clump from scat | - | 3 yrs |
| Foot prints | | 1 hour-1 week |

Sign counts are not appropriate for broad scale survey work, they are best used for monitoring individual species or number of target species. Few investigations have attempted to use sign other than fecal pellets to estimate animal abundance and almost all cases only relative abundance was considered. It is important to remember that counts of signs are simply that, and that can be interpreted in to animals only by calculating from a known ratio of signs per animal (Putman, 1984). Count of signs need not, however be considered as population estimates or animal densities and should be examined simply to document occurrence, status and depending on the aim of the study. As a means of analysing comparative densities, population trends, a sign density index is very useful for large mammals (Hill, 1981). There are various sources of error that often occur in the field most common are the following.

1. Environmental heterogeneity
2. Nonregular production of sign
3. Mobility of animal
4. Detectability
5. Decay rates

To avoid the problems and issues during the sign surveys, use the proper sampling protocols to design the survey. It is also necessary that number of signs produced per animal per unit time be determined independently for each population.

Procedures for animal sign survey and counts are very simple with respect to sampling designs and target species. Mostly, quadrates, transects (strip) are used and animal signs are quantified according to different sign categories. Information for each species should be recorded separately. The number of person required for a sign survey always depends on the size of the area, sampling frequency, habitat type, target species and time available. If possible, the number of persons should be minimum to reduce the interobserver bias. The best results of sign surveys are achieved by single or two persons sample all units.
Some essential materials are required for conducting sign surveys such as data sheets, pen, map of the area, a measuring tape, GPS, marking or flagging material, some references such as sign guide, pictures of signs, tracing material etc should kept with the investigator.

**Sample Datasheet**

*Transect ID:____________GPS Location: Start____________End_____________*
*Date and Time:__________Location & local name of area:____________________*
*Habitat type: _____Start ___________End_____________*
*Name of Observer:________________________Expertise level:_______________*

| Distance | Distance from center | Sign type | Decay/Age | Photo ID | Habitat type | Comments |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |

*Confidence level: 0 = uncertain, 1= reasonably certain, 2= certain*

**Sex, Age and Reproductive Conditions of Mammals**

Determining sex, age and reproductive status of a mammal is very important while studying, monitoring and evaluating viability of a species in the ecosystem as these are the crucial variables reflects the structure and dynamics of a population. Necropsy is the most accurate method to assess these variables; however, it is not always compatible with the natural population. Non-invasive field methods of determining the above variables through external genitalia, secondary sexual characteristics, body size and behaviour can be used, but these may be again vary with the mammalian species. Determination of these variables is largely influenced by the detection limits of the methods, and the expertise of the investigator (Wilson et al., 1996)

**Sex Determination:**

Genitalia:

*Female: Mammary glands, vaginal opening*
*Male: Testes, glans penis*

Body Size, Shape, Pelage and Ornamentation:

*Males are mostly larger than the female of many large mammalian species, but again it is not always a reliable sex determination.*

Scent glands:

*Many mammals have specialized sex specific scent glands which differ in sizeand appearance between the two sexes.*

Behaviour:

*Posture used for urination, mating behaviour, display and aggression (Males)*

**Age estimation:**

There are many field methods for estimating the age of a mammal with varied accuracy. It is very essential for a researchers or managers to assign animal into a broad age classes. More accurate age determination is required in constructing life tables and in demographic analysis. The following table can be used for monitoring mammals in their natural habitats. A combination of body measurement and reproductive criteria offers the best means of determining the age of many mammals in the field (Spinage, 1973).

**Commonly used age categories for Mammals** *(Wilson, et al. 1996)*

**Neonate:** A new born mammal with a detectable umbilical cord.

**Nestling:** A young animal with a limited locomotory and sensory development that has not left the nest

**Suckling:** A mammal before weaning

**Pouch young:** A young marsupial that has not left the pouch

**Juvenile:** A weaned young mammal that still associates with its mother or sibling and may nurse infrequently; usually smaller than sub-adult

**Immature:** A young mammal which is neither fully grown nor sexually mature

**Sub adult:** A young mammal that is not fully grown but that may /or may not be sexually mature or have adult pelage

**Adult:** A fully grown, sexually mature mammal

**Old adult:** An animal that shows extreme tooth wear and /or poor body condition

**Further readings:**

Novak, R.M. (1991). Walker's mammals of the world. 5ed, Johns Hopkins University Press, Baltimore, Maryland, USA.

Wilson, D.E., Cole, F.R., Nichols, J.D., Rudran, R. and Foster, M.S. (1996). Measuring and monitoring biological diversity: Standard methods for mammals. Smithsonian Institution, Washington DC, USA.

Putman, R.J. (1984). Facts from faeces. Mammal Review. 14: 79-97.

Hill, G.J.E. (1981). A study of grey Kangaroo density using pellet count. Australian Wildlife Research. 8: 237-243

Spinage, C.A. (1973). A review of age determination of mammals by means of teeth, with special reference to Africa. East African Wildlife Journal. 11: 165-187.

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