Predators and Prey

nature strikes a balance

K. Ullas Karanth Ph. D

Series Editor, Bittu Sahgal

NCSTC-HORNBILL
NATURAL HISTORY SERIES

Jointly published by:

Vigyan Prasar,
C-24, Institutional Area, ASCI Building,
Behind Qutab Hotel, New Delhi-110 016
email: <vigyan@hub.nic.in>

&

Sanctuary Magazine,
602, Maker Chambers V,
Nariman Point, Mumbai-400 021,
email: <bittu@giasbm01.vsnl.net.in>

ISBN 81-7480-025-5
NCSTC-HORNBILL Natural History Series
Printed in Mumbai, India by Selprint

Predators and Prey

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After decades of field experience, *Dr. K Ullas Karanth* has come to be recognised as one of India's most knowledgeable field biologists, with a deep commitment to wildlife conservation. He has studied predator-prey relationships in the Nagarhole National Park and is currently studying tigers all over India in his capacity as Associate Research Ecologist with the New York-based Wildlife Conservation Society.

Karanth has been widely published around the world and in India. His current project is expected to help sanctuary and park managers in India better understand the circumstances governing the survival of the tiger. Specifically, the study focusses on the correlation between protecting the tiger and ensuring the viability of its prey base.

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NCSTC-HORNBILL
NATURAL HISTORY SERIES

Exclusive Distributers:

UBS Publishers' Distributors Ltd.

5 Ansari Road, ***New Delhi****-110 002*

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e-mail: ubspd.del@smy.sprintrpg.ems.vsnl.net.in

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(not to scale)

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K. Ullas Karanth, Ph.D.

Editor's Note

The Bombay Natural History Society (BNHS) has been a fount of knowledge for over a century. It has created and nurtured thousands of naturalists from all walks of life. Today the Society continues to add to the body of information gathered by all-time greats such as R.W. Burton, E.P. Gee, J.B. S. Haldane and, of course, Dr. Salim Ali, the 'Grand Old Man of Ornithology.' Long before the subject of environment had become fashionable; before the word biodiversity had even been coined, the study of nature was a mission for hundreds of BNHS members. In time this enduring institution gave birth to an amazing network of amateur naturalists. Their prime joy, apart from tramping India's wilds, has always been to share their experiences, knowledge and information about nature with others.

It is in this context that the production of the NCSTC-HORNBILL series should be viewed. India is losing its natural wealth at a frightening pace and it is vital that decision-makers are exposed to the very real value of the ecological assets being lost to the nation. It is equally important that the rationale for wildlife conservation is understood. Humans, for instance, do not possess the technology to re-create the millions of hectares of natural forests, grasslands and wetlands we lose each year.

To maintain and to enhance the green mantle, which protects our soils and our water sources, we need the elephant to transport mango seeds. We also need chital to carry grasses from one part of the forest to the other as we do the tiny leaf warbler's non-toxic 'pest control' contribution. The cleaning service performed by turtles and crocodiles, frogs and the larvae of dragonflies helps make the water in our lakes and rivers drinkable. Every creature on Planet Earth performs a useful ecological role... save for *Homo sapiens.*

We probably started out right, but our capacity for abstract thought, our intellect and our relatively recent penchant for consumerism, have lulled us into the mistaken belief that we can escape the consequences of the grevious damage we inflict on ecosystems and species. With each forest we lose, each river we degrade, each mangrove and coastline ecosystem we alter, the viability of the Indian subcontinent to sustain future Indians is diminished. Simultaneously the quality of life of perhaps over 100 million earth-people: among them, fisherfolk, forest dwellers, nomads and pastoralists... is lowered and their security compromised.

This latter aspect of the environmental and wildlife movements has only just begun to assert itself in our national psyche. Young people everywhere, social activists and human rights groups are fast recognising that protecting forests for the tiger, rhino and elephant automatically serves to protect both forest cultures and resources for communities which live outside the market system.

In the coming days this new partnership between naturalists and earth-people is destined to play a vital role in defending wild India. Towards this end, individuals such as Dr. Ullas Karanth will play a critical role in improving the level of scientific understanding of the wilderness and its wards. If theNCSTC-Hornbill Natural History Series manages to enhance the ecological information base of such initiatives and to replace pure sentimentalism with pragmatism in the battle to save nature... our purpose will have been admirably served.

Bittu Sahgal, Editor
NCSTC-Hornbill Natural History Series

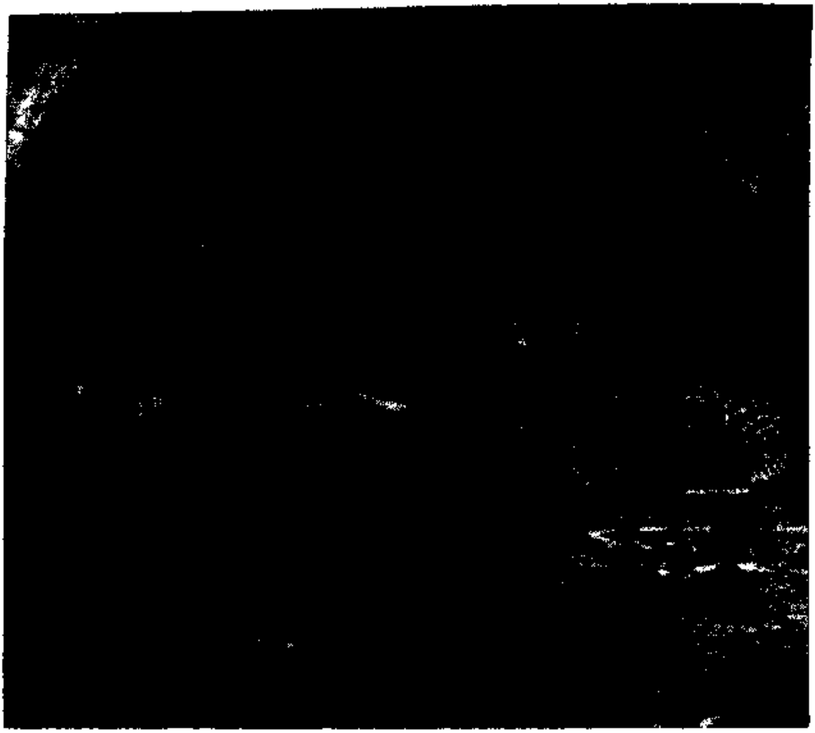
Publisher's Preface

This is one of a series of booklets that have been in the making for years! The wait has been worth it... both in terms of the contents and the fact that we have been able to win the involvement of the most authoritative authors on the various subjects chosen for the titles in the National Council for Science and Technology Communication, *NCSTC-HORNBILL Natural History Series.* NCSTC and the Bombay Natural History Society (BNHS) joined hands to bring the science of natural history to young people though adults too are sure to relate to the style and straightforward presentation. We intend to produce more titles each year to cover as wide a spectrum of nature as possible. We expect the publications to serve the dual purpose of disseminating information and keeping an archival record on the eve of the next millenium.

We wish to demystify the subject of ecology... to make it both understandable and acceptable to India's future decision-makers. The inter-relationships, the complex webs of existence, the contentious and confusing environmental issues... all these will need to be understood and grappled with by tomorrow's citizens. To the extent possible we have stayed away from scientific jargon for obvious reasons. We did not wish this initiative to be reduced to an isolated 'lesson' of the kind one often sees being taught in our schools and colleges.

In this book you will be introduced to the complex, yet fascinating interaction between predators and their prey. Dr. Ullas Karanth is one of India's leading experts on the subject and his on-going study on tigers has already broken new ground. We trust that this (and the other titles in the series) will encourage readers to search for the larger picture, the totality of inter-relationships... and thus better understand our own role on this planet.

Dr. Narender Sehgal, Series Publisher,
Director Vigyan Prasar, June 5, 1997



A chital meets its end in the dry thorn forests of Gir, the last stronghold of the Asiatic lion. Predator-prey systems are subjected to variations in climate, vegetation and water availability. These were all once governed by natural events, but increasingly human-induced changes have begun to affect this fragile ecology.

Beauty with cruelty

The tigress 'Sundari' had been resting in a dense patch of bamboo for the last nine hours that I had been radiotracking her movements. Changes in the pulse-rate of beeps from the tiny transmitter fitted to a collar she wore around her neck told me that she had been sound asleep most of the time, only occasionally rolling over or grooming herself before sliding back to sleep again. She had killed a sambar doe six days earlier, and fed from the kill for four days, eating 90 kilogrammes of meat before abandoning the carcass to vultures. For the next two days she roamed her well-defined home range of 15 sq km in the heart of the Nagarahole forests, but had not made any large kill. I expected that she would be hungry enough today to start hunting again.

At 5.30 p.m., the radio pulses, which sounded rather like calls of a green barbet through the portable receiver slung on over my shoulder, quickened. She was up and moving! I wheeled my green Gypsy around, tracking her movements (which I could not see) using a hand-held antenna. She disturbed some jungle fowl that cackled away noisily, and a langur glimpsing her from its perch atop a *Terminalia* tree, let off harsh alarm barks. A herd of chital, which was grazing placidly, became wary. I saw Sundari cross an open grassy patch growling in frustration, as the chital broke into alarm calls. They watched the tigress from 100 metres away – ears cocked forward, tails erect, thumping the ground with their feet in a typical display of alarm. Ignoring the hysterical chital, she crossed the dusty forest road ahead of me and entered the dense forest on the other side.

Though I lost sight of her, I was still able to radiotrack and follow her movements closely. Through radiotelemetry, and other tools of wildlife science, I was studying the rare and elusive predators of Nagarahole National Park in Karnataka State, considered one of the finest predator habitats in Asia. I picked up her signals half an hour later, near a salt lick. Several gaur grazed placidly in the short grass two hundred meters away. A two-year old male gaur ambled along the edge of the clearing, methodically browsing among the bamboo and *Lantana*. The radio signals indicated that the tigress was shadowing his movements behind the dense cover, but she was still out of attack range. May be the young bull caught her scent, for he suddenly stopped feeding, and cantered away to join his group. Soon, the tigress emerged at the edge of the cover and resumed stalking. She moved, half-crouched till she found shelter behind an anthill, tensed in a position to launch an attack on the grazing gaur. But there was too much open ground to be covered. Totally ignoring my vehicle parked 30 meters away, she waited patiently for over a quarter of an hour, hoping the gaur would drift towards her while grazing. But they moved the other way. Two chital stags, unaware of Sundari's presence, emerged from the cover behind and walked towards her. The tigress sensed their approach and looked back over her shoulder when they were a few strides and a leap from her. But she could not launch an attack without turning around, which meant revealing herself. She made a quick decision, slunk ahead and quickly vanished under cover. Here she turned around and waited for the chital. Despite her lightning fast move, the chital saw her and dashed off with shrill alarm calls. She got up, and looked around with a stoic expression which seemed to acknowledge that 'life was not easy'. This was her third successive failure in the last hour and a half. Soon, she was on her way again, padding stealthily,

"Nagarhole is considered to be one of the finest predator habitats in Asia."

The historical range of the lion once extended from Africa through West Asia into central India, all the way to Bengal. Today they are restricted to the dry deciduous forests of Gir in Gujarat.

The giant panda, Ailuropoda melanoleuca *inhabits the forests of Szechwan in Western China. Though it is essentially a herbivore, largely dependent on bamboo, given the chance it will take small prey such as birds and even fish. This opportunism is a part of the survival strategy of many predominantly vegetarian animals.*

ears cocked to detect the faintest noise, her bright amber eyes piercing the enveloping dusk. Her belly was empty and flat, and muscles rippled under her tawny striped coat. A perfect predator *was* on the prowl.

Though she appeared to be designed as the perfect predator, her success rate in catching prey is anything but perfect. Despite the super abundance of prey in Nagarahole, probably only one in every ten attempted hunts succeeds. The same forces of natural selection that honed this master predator's superb hunting tactics also gifted her prey with ways to thwart her designs. It is a finely tuned balance. How did it evolve... and how is it maintained?

"Is this 'natural balance' a result of some grand external design? In a word... no!."

Evolution and adaptation

We know that plants use minerals from the soil, carbon dioxide from the atmosphere, and the sun's energy to make food, which is then stored in their tissues. Further up in the food chain are the herbivores, ranging in size from tiny insects to huge whales which draw energy by feeding on plankton. Predatory animals that kill and feed on other living animals, are secondary consumers of energy in this complex food web. A simple fact about predators and prey becomes obvious at this point. There should be enough prey to go round, otherwise the predators cannot exist. The fact that complex predator-prey communities have thrived on the earth's changing landscape for millions of years shows that predators have usually not wiped out their prey and driven themselves to extinction as a consequence. Is this 'natural balance' a result of some grand external design?

In a word... no! The balance derives from the evolutionary process of natural selection and pure chance, acting on individual animals in the populations of both predators and prey. Each individual in an animal population differs from others, both in terms of its genotype (the design of the animal locked up in its genes and inherited by its progeny) and its phenotype (external features such as size, coat colour, behaviour). Therefore, the chances of surviving till adulthood and producing offspring vary greatly among different individual animals in a population. Agents of natural selection such as predation, disease and food supply act on the phenotype of the individual animal. How good a particular phenotype is in coping with these pressures, determines whether it survives and reproduces. Of course, sheer luck too has a role in the process, but in the long run, it is the better-adapted individuals that are more likely to survive and reproduce.

"The evolutionary arms race between predators and prey is continuous."

Although, the forces of selection act on the individual animal, they change the underlying genetic make-up of the entire population, because only those animals survive, reproduce and pass their genes on to the next generation. Thus, from among a population of animals consisting of genetically different individuals, natural selection ultimately favours those animals which have genes linked to external traits that are more likely to help the animal survive and reproduce. Such selective forces continuously sharpen the traits that help predators to be better hunters, survivors and reproducers. Simultaneously, similar pressures also enhance the prey's capability to avoid predators, survive and reproduce. This evolutionary arms race between predators and prey is continuous, a war without end, a war without victors.

The adaptive traits of predators and prey are reflected in their physical structure and behaviours. A leopard with a black coat probably has no major problem in the humid forests of tropical Asia where the dense cover and low light levels break its outline and hide it from prey such as muntjac or sambar. However, in the savannas and open forests of Africa or Asia, the same black pelage would probably be far more conspicuous to keen-eyed antelopes or chital. Because black leopards born in humid forests have better chances of surviving and reproducing than those born in open forests or savannas, they are more common in rainforests. The leopard's black coat is an example of a morphological (relating to physical structure of the animal) adaptation.

> ***"Though they are common... not all traits we see in animals have adaptive value."***

Similarly, there are behavioural adaptations. In the open savannas of Africa, the ecological advantages of being able to hunt prey co-operatively, to kill large prey, and to defend prey carcasses from aggressive competitors, have given rise to group-living in lions and hyenas. In the dense forests of Asia or South America, such co-operative hunting may not be feasible and the social defence of a carcass may be unnecessary. Hence the solitary nature of the tiger or the jaguar, predators which evolved in dense forest habitats.

Though adaptation is common in nature, not all the traits we see in animals have adaptive value. We must remember that forces of natural selection are acting in an evolutionary time frame, and, in a changing environment. Predator-prey systems are subjected to variations in climate, vegetation and water availability patterns due to natural, and, increasingly, human-induced events. So, adaptation for one set of conditions may become wholly inadequate if the environment changes rapidly. Therefore, random events or chance also have a major role in shaping evolution. As paleontologist Stephen Jay Gould argues, if we could wind back the clock of evolution fully and let it unwind again, it is very likely that radically different animals – not humans – would inherit the earth. Therefore, when speculating as to why particular ecological traits evolved, we need to be cautious and recognize the role of chance events in the evolutionary process. Gould also argues that the usefulness of traits we now observe in an animal have to be understood in the context of ecological conditions under which they originally evolved.

Size, diet and abundance

"Carnivores are less numerous than the herbivores which subsist on plants."

We know that some animals are common and others are rare. Enter a well-protected forest in south India, and it teems with chital. On the other hand, sambar are relatively scarce and tigers even more so. Why? The relative abundance of animals in natural communities is perhaps the single most important factor influencing all the aspects of predation. The science of ecology is essentially a game of numbers. Therefore, before examining predator-prey interactions, it is necessary to clarify factors that determine the relative abundance of different species in a natural community.

The number of animals of a particular species is determined largely by two factors: the diet of the animal and its body size. Carnivorous animals which eat a rich but relatively scarce diet are less numerous than herbivorous animals which subsist on poorer but more abundant plant foods. Even among herbivores, those which feed on abundantly available resources, such as langurs which eat leaves, are usually more numerous than those like macaques which depend on a scarcer diet of fruits and insects.

Among species having similar diets, the larger ones will be generally be less numerous than smaller ones. Among meat eaters in a forest, there may be more jungle cats than tigers. Among grass eating herbivores (grazers), there will be more chital than gaur. However, a closer examination of the interplay between body size, diet and abundance of mammals reveals interesting variations on these basic themes. Larger herbivores such as chital which consume abundantly available coarse grasses, can be more numerous than smaller species such as muntjac which selectively eat scarce items like shoots or fruit.

"Competition between ecologically similar species may sometimes limit numbers."

Another factor which bears on the abundance of any particular species is its 'social organization', a term which sums up inter-relationships between individuals of different age and sex classes. For example, an aspect of behaviour such as active defence of exclusive home range areas (territoriality) may alter the relative abundance patterns expected on the basis of diet and body size alone. Such territorial spacing mechanisms may limit densities of species as different as tigers and muntjacs. Competitive behaviour among ecologically similar species may sometimes limit numbers of the less dominant species. Leopard numbers appear to be limited in the Kanha meadows of Central India despite ample prey availability, probably due to inter-specific competition with tigers.

Considering how important animals numbers are to virtually every aspect of community ecology, wildlife biologists studying predator-prey relations pay a great deal of attention to measuring them. They measure numbers of both predators and prey in a habitat in terms of population density, or simply as density. This 'density', expressed as number of animals per unit area (such as a square kilometre) is quite different from the term 'density' used by a physicist to express the mass of a material per unit volume!

Habitat and niche

To meet their basic needs of food, shelter and reproduction, animals have to live in a suitable habitat and work at exploiting the resources available. If the habitat of an animal is its 'address', the niche is its 'profession' through which it exploits resources. The habitat of the tiger is the forest and that of the snow leopard is a craggy mountain slope. Since the tiger and snow leopard subsist by killing and eating other animals, they occupy the 'carnivore niche', as do wolves, lions and a host of other predators. On the other hand, the wild buffalo is a land dwelling grass eater occupying the 'terrestrial grazer' niche. The langur monkey occupies the 'arboreal folivore' (tree-dwelling leaf eater) niche in Asian forests, a 'profession' adopted by marsupial Koalas in Australia. Predators usually occupy the carnivore or omnivore niches, but their prey can belong to herbivore, omnivore or even carnivore niches.

"The ecology of predator-prey communities is exceedingly complicated."

With these basic ideas, we can begin to see how exceedingly complex the ecology of an animal community comprising of many predatory and prey species, occupying different niches, living in varied habitats, and occurring at different densities can be! Such predator-prey communities are not merely collections of off-the-shelf animals, but have evolved together over

The tapered upper jaw of the swordfish is no ornament. It is used to slaughter prey. This predatory fish can swim at speeds of up to 70 km/h.

Lesser cats, such as the marbled cat seen at top, are among the least-studied of all predators. The ermine pair seen above belongs to the Family Mustelidae. These awesome hunters are known equally for their exquisite fur and the foetid odour excreted from special anal glands.

millennia in an intricate and often fragile balance. Moreover, even the idea of a stable 'natural balance' is not strictly true, since things are constantly changing. In reality, these communities can be in one of several possible states of balance.

Predators and prey: where are they and why?

Before, examining the predator-prey relations in any detail, a basic question arises. Why are particular predators and prey found in certain regions of the world, but not in others? The historical range of the lion extended from Africa through West Asia into North Western India. The range of the tiger extends from northeast Asia in the opposite direction, until it overlaps with the lion's range at its western extremity. The range of the leopard covers the combined ranges of its two bigger cousins. Though deer of various kinds are important prey for big cats of Asia, in Africa where there are no large deer, bovids (antelopes, wild cattle) form the chief prey.

"Indian fauna is a mixture of past faunas of N. Asia, Africa and Southeast Asia ."

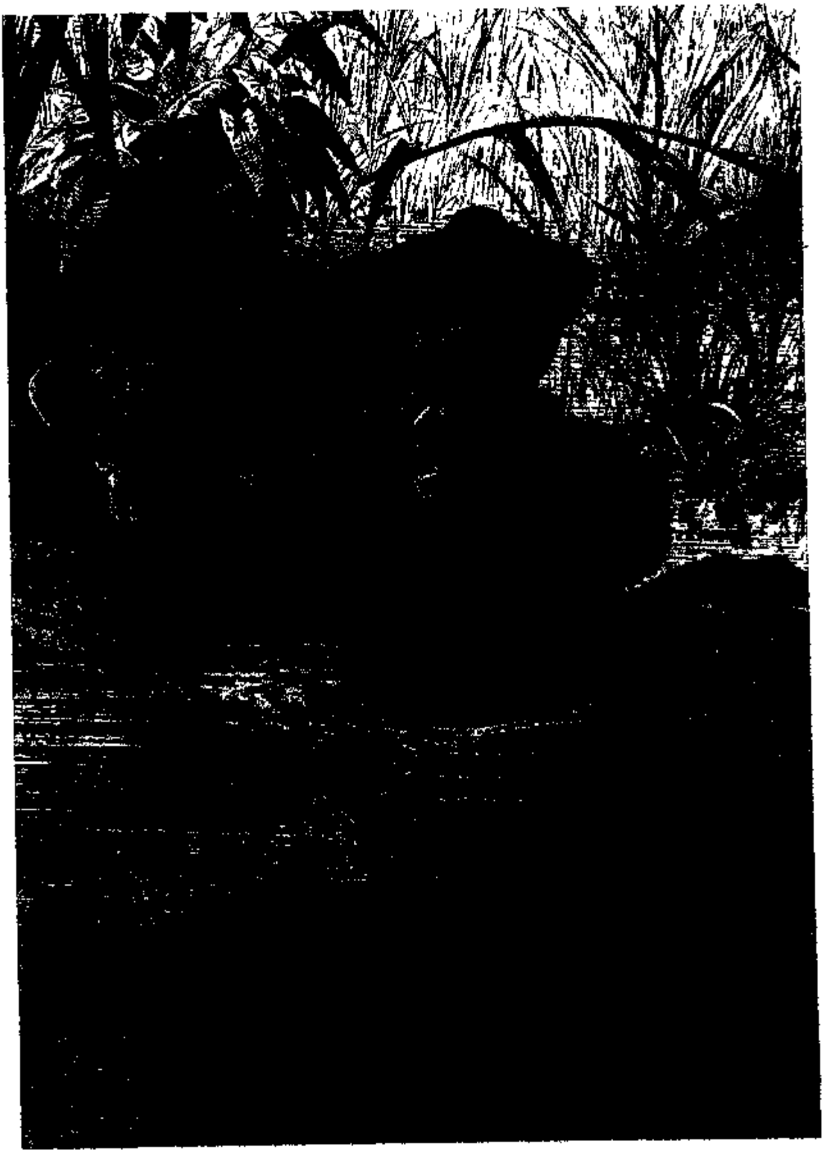
As zoologist John Eisenberg explains in his classic on the subject '*The Mammalian Radiations*'. Current distribution patterns of animal species arise from the adaptations of their ancestors to niches opened up by past climatic, geological and vegetational changes. Indian fauna today is a mixture of elements from the past faunas of northern Asia, Africa and Southeast Asia. Its current composition and richness are consequences of factors as diverse as movements of continental plates, volcanic activity, retreat and advance of glaciers, and the timing of evolutionary radiation of different animal taxa.

If we look at communities of large mammals of the Indian subcontinent, we are awe-struck by the variety of predator-prey communities characteristic to each biotic province. The mountainous and cold desert fauna of the Trans-Himalayan zone has snow leopard, wolf, and dhole as the top predators, preying on many kinds of hoofed prey, ranging from wild yak and wild goats to sheep. In the forested parts of the Himalayan zone, the wolf gives way to the leopard and the tiger, and the prey complement changes to include goral, serow, takin, red deer, musk deer and sambar. In the flat and arid desert zone of western India, the wolf and the cheetah (now extinct) are the top predators on a prey base that includes wild ass, chinkara and black buck. In the dry forests of the semi-arid zone, further eastward, nilgai, four-horned antelope, chital, sambar and wild boar form the principal prey of a predatory guild consisting of lion, leopard, wolf, and tiger, depending on specific localities.

"It is not wise to introduce animals into localities in which they did not occur."

These animals are found where they are because of their morphology, ecology, behaviour and evolutionary history. Therefore, it is not wise to introduce animals across regions into localities in which they did not occur in the past. However, for some strange reason, this is exactly what most people think of doing first. A wildlife manager once had the bright idea of enriching the fauna of Bandipur Park by introducing lions, while another one wanted to introduce rhinoceros into Nagarahole! For that matter, many environmentalists overlook the simple fact that the domestic buffalo introduced by herders to the Siwalik forests is as exotic an intruder as the *Lantana* or *Eucalyptus* found there!

Primitive, human hunter-gatherers, occurring at low densities before they discovered fire, tools, agriculture and animal



Frogs do not generally fit the image of 'predator' but that is precisely what they are. An adult bullfrog is capable of consuming up to half its body weight in insects and other small prey in one day.

Snakes are nest predators against whom birds have little defence other than to build their nests in inaccessible places. Persistent and co-ordinated 'dive-bombing' does however sometimes deter snakes.

husbandry, were truly a part of natural animal communities. People who now live at high densities in and around forests, but depend on agriculture, animal husbandry, the market economy and medical care for their survival, are not a part of such natural animal communities anymore, however primitive their life-styles may appear to be to outsiders.

A fascination for predators

Generally, we consider as predators, those animals that subsist mainly by hunting and killing other animals. While the wolf, the leopard and the shark are clearly predators, monkeys are not, though they do occasionally kill and eat other small animals. Such carnivory by monkeys is not popularly considered predation, since most of their food is derived from plants. The word predator is hard to define scientifically. Zoologists classify cats, dogs, bears, civets, pandas, weasels, raccoons and hyenas which share a common ancestor, and generally feed on other animals, as carnivores. Not all carnivores are considered predators. Carnivores that live primarily by hunting live prey are called predators. The big cats, polar bear, spotted hyena, wolves and wild dogs are clearly predators as are a variety of mustelids and viverrids (weasels, civets, and mongooses). Carnivores like pandas and many bears are usually vegetarians pursuing non-predatory lifestyles. Animals that prey chiefly on insects, ranging from the hyena like aardwolf to tiny bats, are all predators in their own ways, but we do not call them predators.

"Charismatic predators such as the tiger, lion, and jaguar have always fascinated humans."

Charismatic predators such as the tiger, lion, leopard, jaguar, wolf, golden eagle, king cobra, Komodo dragon and the great white shark, have all fascinated human cultures since millennia.

Our awe and admiration for powerful predators are no doubt rooted in own our humble evolutionary origins as minor league scavengers in the African savannas. The puny human hunter who poses grandly with a tiger, which he has shot, is, in fact, exhibiting this deep-rooted sense of inferiority that we all feel in the presence of a mighty predator.

It is perhaps because of this awe that predation has interested modern-day biologists immensely. Scientific curiosity has led to varied questions about predation, many of which are not fully answered yet. How do predators search for, locate, select, capture and kill prey? What are the ways in which several predators compete for and share prey resources in their habitats? What is the impact of predation on prey numbers and behaviour? What are the evolutionary explanations for the patterns of predation that we observe in nature today? And, increasingly, how can we conserve our vanishing predators?

"My own interest in larger mammals undoubtedly colours my view."

Here, I approach these questions from the perspective of a wildlife biologist and focus on describing predation in nature from a point of view relevant to the conservation of predator-prey communities. This is not to down-play the importance of seeking evolutionary explanations concerning predation, but merely to highlight the fact that explaining predator-prey interactions in ecological rather than evolutionary terms is of greater urgency in these critical times. My own interest in larger land mammals undoubtedly colours my view of predation. But I have no doubt that predatory interaction involving birds, fish, amphibians, reptiles and insects are all equally fascinating subjects.

The importance of being eaten

Because of their charisma and glamour, predators attract more attention than their prey species. Everybody wants to know how many tigers there are in a reserve but no one wants to know how many deer there may be! Even in our major conservation schemes like Project Tiger, while every one harps on counting the tigers, scant attention is paid to the status of prey animals. Yet, prey populations hold the key to the very existence of predators. While prey populations can thrive in the absence of predators, predators simply cannot survive without prey. In this chapter, I examine factors related to the ecology and behaviour of prey, which are important for understanding predation.

"The larger the predator, the greater the energy spent in finding and killing prey."

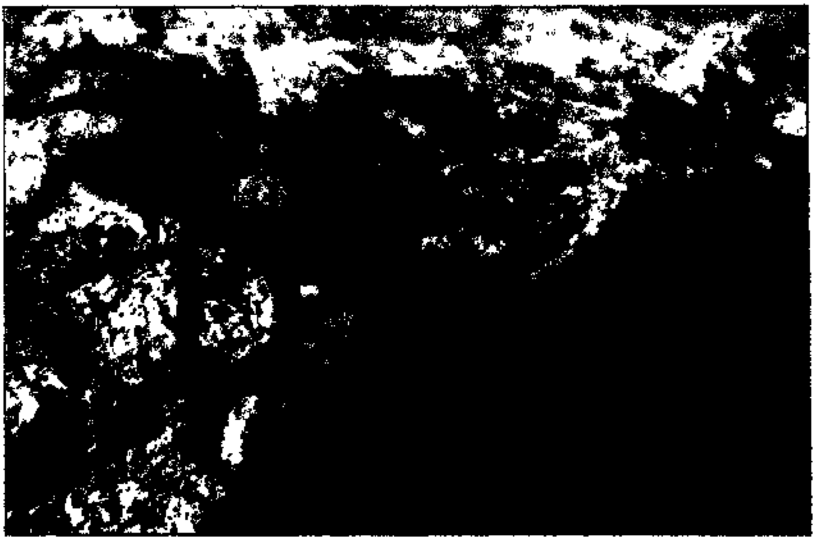
Some predators typically specialize on a few prey types, whereas others are generalists killing a wide range of prey. I found that about 95 per cent of the meat eaten by tiger, leopard and dhole in Nagarahole came from just five species of prey: gaur, sambar, chital, wild boar, muntjac and langur monkey. Small prey such as hare, rats, porcupine and chevrotains were killed, but their contribution of meat to the diet of large predators is negligible.

A predator expends considerable energy in finding and killing each prey. The larger the predator, greater is the amount of energy spent in this act. This energy expenditure sets limits on the size of prey needed to sustain a predator. It has been estimated that on an average a tiger needs to kill about 3,000 kg of live prey in a year to survive. Thus roughly about 50 prey animals weighing about 60 kg are needed to sustain a tiger over a year. Instead, can the tiger sustain itself by killing 12,000 rats weighing 250 grams each? No. The amount of energy expended by the tiger for catching each rat would be far more than the nutritional energy it gets from the rat. It would be like a man who runs 25 kilometres to eat a biscuit. Therefore, it is not possible for large predators to live off very small prey alone, though occasionally they may take such prey if it comes their way. Tigers cannot live off prawns in mangrove swamps devoid of large prey, nor can lions live off grasshoppers in the savannas, although such small prey may in fact be the most abundant. The prey has to be large enough in comparison to the predator's own size.

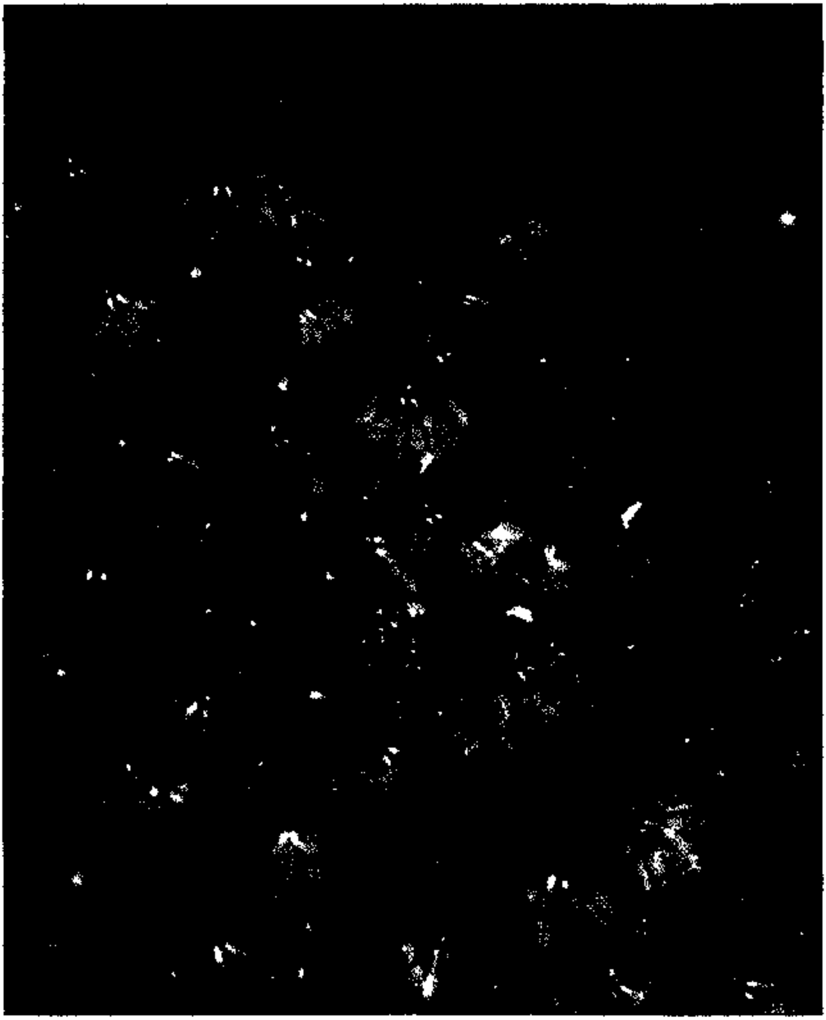
> ***"There is a world of difference in the way tigers hunt in Siberia and India."***

A predator on the prowl has to encounter a prey animal before it can try to catch it. This encounter rate between predators and their prey depends significantly on population densities of prey. If there are five chital groups per square kilometre of habitat for every group of sambar found there, the odds are five to one that the next prey to be encountered by a prowling leopard will be a chital. Thus density of the right sized prey is probably the single most important factor in determining how suitable an area is for predators. Which is why there is a world of difference between how tigers make a living in Siberian forests with 2-4 large prey per square kilometres and the life-styles tigers in prime Indian forests packed with twenty five times more prey.

Although prey may exist at high densities, they may not always be available. In Africa's Serengeti, wildebeest migrate from the open plains and are simply not available through the year to the resident lion populations there. Wolves and snow leopards in India that prey on livestock belonging to nomadic pastoralists may face similar constraints.



Density of the right sized prey is probably the single most important factor in determining how suitable an area is for predators. This holds good for cats that prey on mountain sheep and goats... and for spiders that prey on tiny life forms no larger than a fly.



While flowers may seem aesthetic to human eyes, the fact is they represent bloody battle fields where predator and prey engage in mortal combat. Some praying mantis and spiders will, for instance, take on the colours of blooms and then wait to ambush insects that arrive in search of nectar. Carnivorous flowers have themselves taken on the predator's mantle! They lure insects and then devour them with the aid of powerful digestive juices.

Physical defences

The prey species possess several physical and behavioural defences against predators. Elephants, hippos, and rhinos escape predators as they are physically too big to be tackled successfully. Adults of these species are, as a rule, too large for even master predators like tigers or lions.

Some prey have developed an arsenal of mechanical and chemical weapons of defence. Porcupines have deadly quills, which they are only too willing to use, as many blind leopards and tigers might testify. Pangolins and tortoises possess tough scales or shells. Skunks, which are cat-sized North American mustelids, use a powerful and noxious spray of chemical from anal scent glands to temporarily blind and deter their predators. Some reptiles save themselves by losing their tails to predators while they escape, only to grow a new tail. Though this entails considerable investment, it is well worth the cost considering the opportunity to escape 'to live another day.'

"Most prey animals have shapes and colours which help them escape from predators"

Most prey animals have shapes and colours that help them to escape from predators. A speckled and flecked coat of browns and whites helps prey such as chital and chevrotain to blend with their surroundings in sun-dappled forests. Even striking coat patterns such as those of the zebra or Malay tapir, in fact, break up their outlines in their specific habitats, and make detection by predators more difficult.

On the other hand, several insects look like other species which are noxious or which sting, to fool the predator into leaving them alone.

Behavioural defences

Prey can also gain safety from predators by their habitat selection behaviour. The selection of short grass areas bereft of stalking cover by antelopes to avoid lions, or the choice of extremely steep cliffs by mountain goats to avoid wolves, are examples of such defences. Chital congregating around camps in several Indian protected areas probably do so to escape from their animal and human predators.

Although several mammals and birds sport weapons such as antlers, horns, beaks and spurs which are very effective in fights among their own kind, these weapons rarely seem to be useful against predators. Chital stags appear to have little use for their razor sharp antlers against dholes, even when desperately cornered. Similarly, the massive horns of the gaur seem useless against attacking tigers.

"Most anti-predator behaviour involves passive defence."

On the other hand, zebras may use kicks to disable lions. I once saw a sambar protecting her fawn from five dholes with her flailing front hooves. Aggressive defensive behaviour in which individual members of potential prey gang together to counter-attack and chase predators has also been recorded in several other species such as elephants, African buffalo, baboons and chimpanzees. Such 'mobbing' to deter raptors is quite common among birds. However, as a rule, most anti-predator behaviours involve passive defensive mechanisms rather than offence. Prey animals usually either hide to avoid detection or flee rapidly to escape capture. 'Freezing' in mid-motion to blend with the surroundings is seen in deer fawns, adult muntjac, and several ground dwelling birds like quail and partridge. A variation on this theme involves deliberately feigning death, a tactic that works with predators that are biologically programmed to attack moving prey or those which do not eat carrion. Opossums of course, are famous for playing dead, but even large animals like hyenas sometimes resort to this technique.

Escape through fleeing is perhaps the most common anti-predator behaviour. We see it in its purest form in the fleet-footed antelopes and gazelles of the savannas. These animals reach astonishing speeds exceeding 100 km per hour, and keep going for miles. Given a good head start even the fastest of predators like cheetahs have little chance of catching them. Forest animals such as gaur and sambar, dash away impulsively at the slightest suspicion of a predator stalking nearby. Flocks of duck or pigeons dive rapidly when attacked by falcons. Fleeing gazelles try to shake off chasing predators by twisting, turning and dodging unpredictably, to gain that split-second advantage which may mean the difference between life and death. Diving into thick cover like a hare, or disappearing down a hole like a snake, or scaling up a tree like a monkey, are all behaviours that serve the same function in the desperate struggle for survival.

"Each individual in a group benefits from the vigilance of the others."

Though group living behaviour among animals is more likely to have evolved as an adaptation for efficiently exploiting food resources, evolutionary theorists argue that reduced predation risk may also have contributed to the evolution of group-living among prey. A fundamental evolutionary advantage of group living, as opposed to solitary living, is that the probability of each individual prey-animal being attacked by a predator is considerably reduced in the former case. In addition, each individual in a group benefits from the vigilance of other individuals in detecting predators. Deer alarm signals such as calls, foot stamping and tail flashing are different tactics used to share information about a predator among group members. Biologists also speculate that in some cases such alarm behaviour may even be directed at a concealed predator. Since many ambush predators give up stalking if they think the prey has seen them, such pre-emptive signaling may help in flushing out a predator whose presence is merely suspected by the prey.

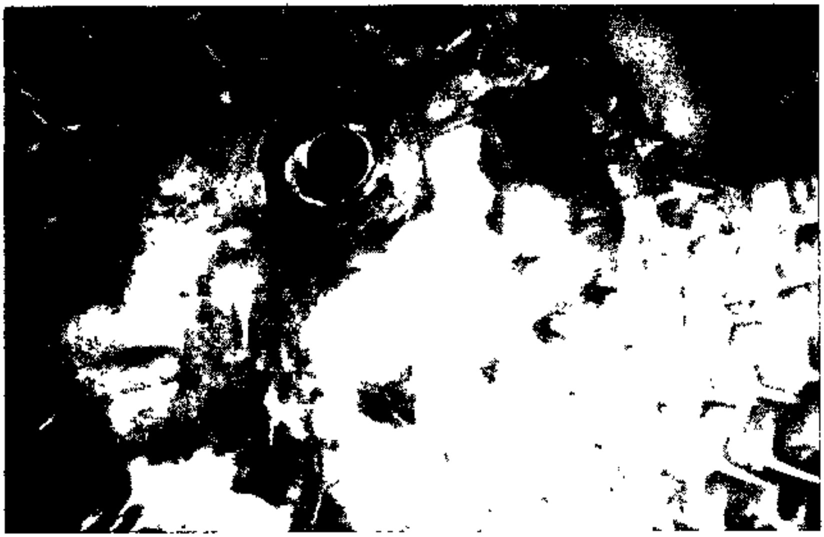
Usually a predator attacking grouped prey selects its quarry in the early stages of the attack. A large number of animals just mindlessly milling about can confuse an attacking predator in the first critical seconds of the attack, by making it difficult to select a particular individual for attack. Such behaviour, thwarting predation has been reported for lions attacking milling groups of wildebeests and for hawks attacking large flocks of birds.

"Canines are morphological adaptations... group-hunting is behavioural adaptation"

Predatory adaptations

Predators need to be adequately equipped to overcome the physical and behavioural defences of their prey. Such predatory adaptations may be related to the morphology of the predator or to its behaviour. Large canine teeth we see on big cats are a classical example of a morphological adaptation. On the other hand, the group-hunting behaviour of the spotted hyena is a behavioural adaptation. It is the fine-tuned combination of these two kinds of evolutionary adaptations that result in the functioning 'design' of the predator. We must note that a predator genetically inherits behaviours that enable the most effective use of its physical armoury. Predatory behaviour is as much a

Hooked beaks and sharp eyes are evolutionary gifts that enable raptors to spot animals from great heights from where they can swoop down on prey. Grasping talons complete the arsenal to allow the birds to take on even such lethal prey as snakes.



The puffer fish (top) can swell its body dramatically to dissuade predators. The moray eel (below) predates on fish and molluscs in coastal waters. Its warning colours probably send out a signal to larger predators, informing them of the toxicity of its own blood.

part of a predator's design as its morphology. A wild dog that attempts to stalk, ambush, and kill by delivering a lethal bite to the throat in the manner of a leopard has little chance of success. Its body simply does not have the spring like qualities necessary for stealthy stalking. Nor does it have the powerful jaw muscles, long canines, and grasping claws of the cat, which would enable it to deliver the killing bite to the prey's throat. In contrast, the wild dog has a lithe body suited for the tireless chase and a long narrow muzzle capable of biting a prey on the run, traits that combine to bring the prey down from exhaustion and loss of blood.

"The polar bear is the largest present-day land predator on earth."

Predators large and small

Perhaps the single most important aspect of a predator's basic design is its body size. The largest land predators such as the extinct dinosaur *Tyrannosaurus rex* (of Jurassic Park fame), probably weighed over 20 tonnes, and killed other herbivorous dinosaurs four times their own size. We simply cannot have a land-dwelling predator as big as *T. rex* now, because a sufficient number of large prey needed by such a big predator do not exist. During the Miocene (about 25 million years ago), considered to be the golden age of mammalian evolutionary diversity, several elephant-like animals, and giant versions of present-day tapirs, rhinos, hippos and sloths roamed the earth. Preying upon them were a wonderful array of the much larger ancestors of present day cats, dogs, hyenas, and bears. In tune with a decline in prey size, present-day predators are much less spectacular. The polar bear weighing about 700 kg is the largest among the present-day land predators, while the smallest weasels weigh less than one thousandth as much.

Mammalian predators are members of the order *Carnivora* and belong to the families *Felidae* (cats), *Canidae* (dogs), *Viverridae* (civets and mongooses), *Procyonidae* (Raccoons), *Hyaenidae* (Hyenas), *Mustelidae* (weasels) and *Ursidae* (bears). Of these only the some members of the cat, dog, hyena and bear family are large. Only such large predators can kill prey much bigger than themselves. Big cats such as tiger, lion, leopard and puma show extraordinary prowess in killing prey five to six times heavier than them. Most of the other predators are built to kill smaller prey.

Finding prey

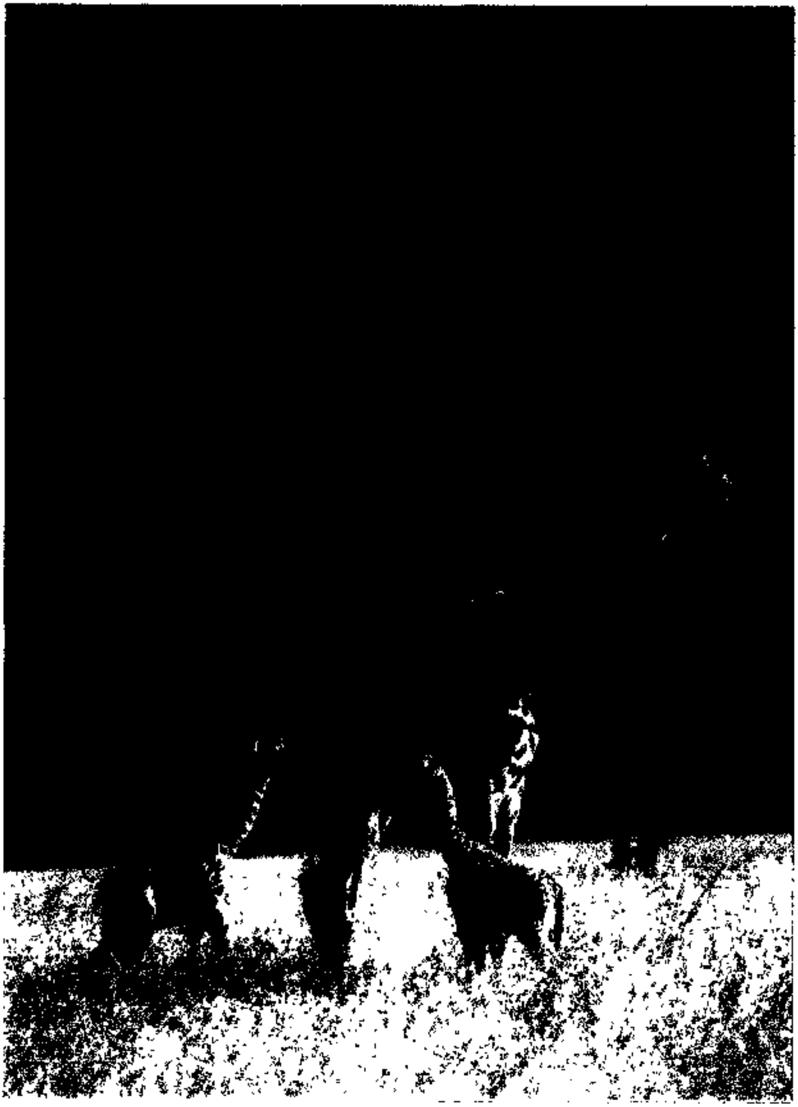
"Cats such as tigers, leopards, and lions can kill prey larger than themselves."

Apart from possessing the right sized body, predators need sensory mechanisms to detect and locate prey. These senses should be superior to those of their prey, to provide that crucial element of surprise in the act of predation. Predators locate prey by detecting visual images, or by its vibrations, smell, warmth or touch, through their senses. These different sensory capabilities are used in varied combinations by different predators.

Sight is important for predators that live on land. Most predators which hunt by sight, detect movement of its prey rather than its still form. Big cats including the snow leopard have eyes and neural networks which can gather images at low light levels, even though their colour discrimination ability is poor. On the other hand, members of the dog family such as wolves and wild dogs have poorer vision in low light levels, and hunt primarily during the day. Falcons which hunt by day have acute vision. Note how frequently a kestrel can detect a tiny mouse in the swaying grass far below! The owl which hunts at night does the

Apart from possessing the right sized body, predators such as the snow leopard seen here need sensory mechanisms to detect and locate prey. These senses must be superior to those of their prey, to provide that crucial element of surprise in the act of predation. Mountain goats and other prey species across the world which must evade high altitude carnivores use camouflage and are exceedingly fleet-footed.

Few predators have quite managed to capture the imagination and respect of people around the world as the tiger. This magnificent animal is, however, being hunted to the point of extinction by the arch predator... man.



An adult giraffe is relatively safe from predation, even by lions that have learned to keep away from their flying hooves. Young giraffes, however, are vulnerable and must stay close to their parents for protection.

To supplement their acute sight which enables them to hunt at night, owls have also evolved special feathers which allow them to fly silently, thus avoiding detection from sharp-eared prey.

same by being able to see infra-red radiations emitted from the warm body of the mouse.

Sounds are actually vibrations travelling through air or water. Predatory mammals, birds, and some reptiles pick up these vibrations through their ears to locate prey. Most snakes pick up sound vibrations from the ground through bones in their bodies. Similarly, the bodies of predatory fish pick up sound vibrations borne through water. The Vibrissae or whiskers on mammals such as otters and shrews may also be used for sensing vibrations. Insect-eating bats are well known for their ability to locate prey by detecting sonar echoes. These bats continuously emit sounds, which bounce off surrounding objects. The bat's sonar system picks up the rebounded vibrations and helps it to navigate and locate prey. Most mammalian predators have large pinnae earflaps that help to funnel sound vibrations into the ear. If you observe a cat hunting, it is easy to see how it moves its earflaps constantly to locate source of sounds made by potential prey.

"The owl is able to hunt in the dark by detecting infra-red radiation from body heat."

The sense of smell is acute in many land predators, particularly among members of the dog family. Compared to a human nose, a dog's nose has probably 40 times more smell-receiving cells! Although cats commonly communicate with each other through scent signals deposited on the ground or in vegetation. They do not appear to use air-borne scents while hunting. Avian predators also do not rely on the sense of smell. However, the sense of smell is an important tool for prey detection among predatory fish such as sharks, which operate in murky under-sea habitats.

Snakes such as pythons, pit vipers and rattlesnakes are able to detect temperature changes in their vicinity caused by the presence of warm-blooded prey. The heat receptors around their facial pits or jaws even enable them to locate their prey and strike with deadly accuracy. Some predatory fish detect prey by touching it, or, even tasting it through mobile and taste sensitive projections on their faces.

Predatory strategies

After locating a prey the predator has to get close enough to catch the prey. Once again we see a wide range of predatory strategies in this aspect of predation. Two types of strategy however tend to dominate predatory behaviour.

> ***"A well camouflaged predator will simply wait for prey to bump into it."***

The first strategy consists of pure ambush. A well-concealed or camouflaged predator simply waits for the prey to almost bump into it. There are several variants of this strategy of pure ambush. The insect killer, the praying mantis, resembling an innocuous twig or leaf, waits to seize an unwary passing prey. The coiled viper concealed under leaves does the same. Other predators rely on an amazing array of technologies to draw the prey closer. Some spiders weave complex webs, while others build elaborate ground traps. The archer fish spits out a jet of water as far as two meters to catch its insect victims, while the chameleon darts out a long sticky tongue to ensnare its prey. Sea anemones, jellyfish and corals demonstrate other variants of the strategy of snaring prey after simply waiting for them to come within range. Usually the strategy of pure ambush is adopted by lower organisms that feed on abundant prey.

Higher animals that actively hunt for their prey commonly use the second strategy. These hunters are 'stalk-and-ambush' predators like the tiger, leopard or the lion. Or they are 'coursing predators' like the wolf, wild dog or the cheetah which run down their prey after fairly long chases. The former have padded feet, perfectly balanced sinuous bodies, heavy build, the ability to remain motionless for long periods, and the tremendous leaping abilities needed for their deadly ambuscade. The coursers have lighter bodies, long legs with toes and pads built for running, and great stamina to tirelessly chase after their prey.

Strikingly similar to these hunting strategies of land predators are the hunting methods adopted by raptors. While hawks and hawk-eagles prefer to wait and pounce on passing prey at short range under the forest canopy, falcons prefer a long and rapid chase in the open skies to capture their prey. The former have broad, rounded wings for dodging rapidly through cover, while the latter are equipped with long-pointed wings capable of attaining incredible speeds of over 250 kilometres per hour.

"To avoid injury a predator must immobilise its prey right after the attack."

Capture and consumption

Having caught its prey, the predator has to quickly subdue the victim before eating it. As we have already seen, many prey species have formidable anti-predator defences which are capable inflicting lethal damage to the predator. Therefore, immobilising the prey immediately upon attack is vital. Some snakes like the cobra use poison to immobilise prey, whereas others like the python do so by coiling and compression. But most predators use teeth (or beaks) and claws to subdue and kill their prey. They usually have sharp canine teeth or beaks specifically designed for puncturing the windpipe, severing blood vessels or ripping open the belly of the prey. Most spectacular examples of such specialized teeth were seen in the extinct sabre-toothed cats that hunted large, thick-skinned elephants, zebras and sloths. Most predators have sharp, hooked claws that are used to grip and manipulate prey while delivering lethal bites. The killing process is comparatively easy if the prey is small relative to the predator. However, when prey larger than themselves are involved, the predators have to be careful. For example, when bringing down large hoofed animals, big cats grip their throat and strive to keep away from the flailing hooves. I have observed that tigers sometimes hamstring adult gaur to disable them before finally killing them.

"Tigers sometimes hamstring gaur to disable them before finally killing them."

The feeding structures and digestive systems of predators vary considerably. The cheek teeth of cats and dogs are designed for shearing off chunks of meat before swallowing them. Carrion-eating hyenas sport the biggest cheek teeth, specially adapted to cracking up large bones. On the other hand, predators that only eat small, soft prey such as insects usually lack shearing teeth.

A predator's diet of meat is nutritionally rich, unlike the low quality diet of herbivores. In contrast to a herbivore that has to feed continuously and digest enormous quantities of forage, an equal sized predator can go without food for several days. Consequently, the stomach and gut of a predator are relatively compact, allowing for the more sporty body design essential for the predatory life-style. However, finding and catching prey involves much more effort than finding plants to feed on. Further, prey capture is not guaranteed. Therefore, predators have evolved digestive systems that can adapt to a feast or famine regime. While a tiger may spend 18 hours of the day sleeping, or kill only once in a week, it is also capable of eating one fourth of its own body weight during a single meal!.

A fine balance?

From what we have seen earlier, it is clear that predator-prey interactions are complex. They involve not only the relationship between predator and prey species but also the ecological interplay between prey populations and their food resources, as well as interactions among different predators. As a result, predator-prey relations remain poorly understood in most ecosystems, even to this day.

> ***"Predator-prey relations are poorly understood in most ecosystems to this day."***

Despite several years of scientific research, the role of predation in regulating prey populations remains unclear. However, the available data suggest that many popular notions about predators, prey, and 'balance of nature' may be too simplistic.

One of the most important aspects of predation is prey selection. The prey population consists of several different species of prey. Within each species there are variations between individual animals because of differences in age, sex and reproductive condition. A predator is said to be 'selecting' prey, if it hunts animals of a particular species (or age-sex category) disproportionately in relation to its numbers in the prey population.

Do predators only select 'unfit individuals' among prey, thus maintaining the health of the prey populations? If so, one would expect only old prey animals past their reproductive prime, or diseased and injured individuals, to be killed. There is some evidence that when adverse climate or disease disable a large number of prey, unfit individuals are heavily preyed upon by predators such as hyenas, wolves, and lions. I observed heavy incidence of tiger predation on gaur affected by foot-and-mouth disease in Nagarahole. However, most field studies of large predators such as lions, tigers, pumas, hyenas and wolves show that while predators do take unfit individuals, there also appears to be heavy predation on young animals, adult males in prime condition, and sometimes, on pregnant females.

The young prey is less experienced in escaping from predators. The gravid females are handicapped by the weight of their fetuses. The adult, male ungulates tend to be solitary, a behaviour which increases each individual's chance of meeting a predator on the prowl, as well as depriving it of a group's shared vigilance.

"Predators profit most by opting for the largest possible prey they can safely catch."

Male deer in hard-antler are thought to be less attentive during rut and may even be more conspicuous targets for attack. The point is simply this: predators take prey which they can easily catch, rather than merely 'weeding out the unfit' as is sometimes popularly believed.

A factor that influences the prey selection process strongly is the size of prey. As we saw earlier, it is energetically more 'profitable' for predators to select the largest prey they can safely catch. David Scheel has reported evidence of such energy-maximising foraging tactics among African lions. In Nagarahole National Park, I observed evidence of selection for the less numerous but larger gaur and sambar by tigers in preference to the much more abundant chital.

However, where large prey are scarce, tigers select chital as observed by George Schaller in Kanha National Park, India, and by Mel Sunquist in Chitwan Park, Nepal. When compelled to do so, due to decrease in large-sized prey from poaching, tigers subsist by killing the even smaller muntjac, as noted by Alan Rabinowitz when working in Western Thailand.

Predator-prey numbers

If predators have to survive in the long run, they have to 'crop' available prey populations in a sustainable manner. This 'sustainable harvest' does not result from any conscious effort on the part of predators. Although, predators generally do not kill more than what they need, there are occasional reports of surplus predation. Such aberrant behaviour occurs when the killer instincts of predators are triggered off by the helplessness of the prey which are unable to escape for some reason. Ecologist Hans Kruuk reported such an incident in which a spotted hyena pack wastefully killed 110 Thomson's gazelles trapped in a rainstorm. Tigers or leopards that get into cattle pens sometimes rampage similarly.

"A spotted hyena pack wastefully killed 110 Thompson's gazelles."

If predators increase to numbers beyond that which the prey base can sustain, they can sometimes drive prey populations down drastically. Though not common, such occurrences are occasionally reported, particularly from isolated islands or parks, where declining immigrants do not augment prey populations and temporary surpluses in predator populations cannot disperse. Monitoring predator and prey populations closely in our nature reserves is vital for this reason.

What proportion of the standing crop of prey is killed each year by predators? Studies by George Schaller and Hans Kruuk on lions and hyenas in Africa, by A. J. T. Johnsingh on dhole and my own work on tigers, leopards and dhole in Nagarahole, all suggest that about of 10-15 per cent of the ungulate prey are killed every year by such predators.

Ecologist Louise Emmons, working in Peruvian rainforests found that a medium-sized cat like the ocelot annually crops as much as 40 per cent of its fast-reproducing rodent prey base. The social behaviour of predators, such as defence of territories to exclude other breeding animals, and the long-distance dispersal of newly-independent young, usually keep predator densities within limits set by prey availability. If prey become scarce due to any reason, predator survival and reproduction rates decline, ultimately reducing predator numbers.

"Predator densities will usually be kept within limits by prey availability."

Studies in North America and the African Savannas suggest that if large scale mortality of prey species occurs on account of factors such as adverse climate or disease, then these factors rather than predation may be important in controlling the numbers of prey species. On the other hand, in tropical forests where predators are important contributors to mortality, predation may have a considerable regulatory role.

Generally, the evidence from field studies suggests that populations of prey species which occur at relatively low densities are more likely to be regulated by predators, whereas more abundant prey species, such as wildebeest or chital, may be regulated by food supply or diseases. In any case, there is compelling scientific evidence to show that prey densities largely determine how many predators can be supported in a given habitat.

Baboons are Old World monkeys that are found only in Africa. They live highly organised social lives and though they forage for fruits, buds and roots they will readily gorge themselves on insects and bugs. They predate on bird's nests and have also been known to use their sharp fangs to collectively bring down and eat small gazelles. Adult wart hogs are formidable opponents and are given a wide berth by most predators. Young ones, however, are very vulnerable to predation and must therefore stay close to their parents.

To evade being eaten, young fawns are programmed to stay quite still when left unprotected by their parents even for short durations. The spots are intended to disrupt their outline, an effective strategy in the dappled light under bushes and tall grass.

Desert foxes found in Africa, North America and Arabia are characterised by their extraordinarily large ears which can pick up the slightest sound from a distance to detect their prey.

Ecological constraints for predators

Their diet of meat imposes some major ecological constraints on predators. Even an old or disabled herbivore can prolong its survival by feeding on available forage and may gradually starve to death over months or even years. A vast majority of India's cattle are living examples of this process! On the contrary, a disabled predator, unable to hunt, meets a brutal death from immediate starvation. A 240 kg male tiger, radio-collared in Nagarahole, starved to death within three months of being injured in a fight with another tiger.

"Tiger cubs learn to hunt from their mothers over a period of two years."

Because of the need to hunt continuously, a female predator can not afford to carry a large fetus. Therefore, predator cubs are born early. For example, though a 50 kg chital female has a gestation period of eight months or so, a tigress who is three times larger, gives birth only in 3.5 months. Consequently, predators are small and helpless at birth. They cannot escape from danger on their own for quite some time, unlike the young ones of their herbivorous prey. Further, young herbivores can independently forage on their vegetarian diet within weeks, whereas, young predators depend entirely on their mother to feed them. Tiger cubs for instance, gradually learn to hunt from their mother over a couple of years.

This dependence of helpless young on their mother has major consequences for her predatory life style. Firstly, she can raise her cubs only in prey-rich areas where she is reasonably sure of catching sufficient prey to meet their heavy nutritional demands. A tigress with three large cubs has to kill twice as much prey as she would have to just to feed herself. Secondly, her hunting activity is restricted to areas within easy reach of her litter. Therefore, although adult predators may just about manage to survive in areas of low prey density, availability of high quality, prey-rich habitat holds the key to successful reproduction, and, to the long time survival of predator populations.

Predators fascinate most people. A fair number among them understand that predators, which are at the apex of biotic communities, are not merely powerful cultural symbols. Predators provide us with an excellent gauge for the overall health of ecosystems that they inhabit. Predator conservation is the only quick and practical way of preserving entire biological communities. Predators are like a protective umbrella under which all biodiversity thrives.

"Predators are like a protective umbrella under which all biodiversity thrives."

Although most environmentalists readily appreciate these principles, relatively few understand what is involved in predator conservation in the real-world. Thus, the naive idea that predators and people can harmoniously co-exist inside conservation areas without any conflict is gaining ground. But reality, dictated by the basic biology of humans and predators – two large mammal species with similar diets, is very different.

Man-animal conflict: an ancient legacy

Though predators such as lion, tiger and the jaguar have been glamourised in religion and art by human cultures across the globe for millennia, there can be no doubt that man and predators have been serious competitors all through this period. The reasons are not far to seek. In the distant past our ancestors such as the *Australopithecus* roamed the African savannas in bands, like baboons and hyenas do to this day. They were in

The bird eating spiders of Costa Rica, popularly called tarantulas, prey largely on insects, though they will sometimes take tiny birds and mammals the size of a mouse

Bears are the largest carnivores in the world. Ironically, they are among the least dependent on meat for their survival! Their dental formula is the same as that of dogs, but they have crushing teeth to enable them to consume plants. The brown bear seen here, Ursus arctos, *is the most common of all the bears. North America has several species of brown bear that are so similar that some naturalists club them together and treat them as one species.*

constant fear of the large predators that shared their habitat. It is unlikely that our primitive ancestors exerted any serious hunting pressure on predators directly. But, by simply being large-sized omnivorous mammals, they hunted the same prey animals as the predators. It is likely that they also stole predator kills, and were sometimes preyed upon by the predators. Because of such head-on, ecological competition for the same prey base, humans and predators had an adversarial relationship. Comparisons of prey killed by predators and by primitive hunters show that both of them compete for the same prey base. This is evident even today, where such indigenous lifestyles prevail.

"All over the world, governments offered bounties for the death of predators."

Therefore, man and his ancestors have indirectly influenced predator numbers even in that dim, distant past. With cultural and technological advances such as use of fire, tools, and later, agriculture, the dice became loaded in favour of humans in their evolutionary gamble with predators. Through large-scale habitat modification, man was able to exclude his most serious predatory competitors from his habitations. With the advent of livestock-raising cultures, the conflict between predators and man intensified. However, new weapon technologies helped man to hold predators at bay. Finally, with the advent of firearms and other products of the industrial revolution, humans established complete dominance over predators. All over the world, governments offered bounties for killing predators. The predators were, finally and irrevocably, in retreat.

There is a commonly held notion that predators are dangerous animals that habitually attack people. Actually over several thousand years predators have come to fear man for his devastatingly superior arsenal. They have long been shaped by evolutionary survival instincts to shun humans and flee from them. Constantly persecuted and harassed by man over thousands of years, a tiger simply does not look at a human being and a cow in the same light: its instinctive behaviour of hiding and fleeing from us is just too strong. It is for this simple reason that thousands of people live in daily proximity to large predators such as the big cats, wolf, wild dogs, hyenas and bears all over the world. It is by avoiding man, and not by attacking him, those predators have managed to survive to this day.

The occasional man-eating big cat or killer wolf is an aberration. Such man killing usually results from a freak accidental contact of an injured, starving, inexperienced, hungry predator with a human being in a vulnerable position. However, once having discovered human vulnerability, the quick learning predator may lose its instinctive fear of man and start viewing people as simply another abundant prey species. Sometimes, such predatory behaviour may be passed down from mother to offspring, leading to endemic man-eating problems. Whatever the cause, such man-killing behaviour is not at all typical to a vast majority of predators.

"Predators have come to fear humans because of our superior arsenal."

Can we save the predators?

Over the last several centuries, agricultural activity has changed the face of the land. Vast stretches of forests, savannas and swamps have been cultivated, destroying habitats, eliminating the prey base, and bringing predators into increasing conflict with humans. As a result, barely four per cent of the land area of our country now consists of areas set aside for wildlife conservation. Even out of this tiny fraction of land, probably only half comprises of areas suitable for large predators. Even within these last refuges, substantial and rapidly increasing human populations are seriously jeopardising the very survival of natural predator-prey systems. The pressures which people living in and around our protected areas, put on predator populations are many and varied.

Illegal hunting is probably the most important adverse factor. Although spectacular illegal hauls of predator skins and bones which make headlines in the press cannot be ignored, it is the persistent and wide-spread poaching of prey species which poses a far more serious threat to predator survival. Poachers of prey animals come in all hues: the local villager misusing his crop-protection gun, the *adivasi* with his snares, traps, nets and other traditional but deadly techniques; the small-town poacher who arrives by jeep; and, the affluent, urban delinquent. Except the last category, all other types of poachers usually sell their harvest in local or distant illegal markets that are virtually bottomless pits. Consequently, poaching depresses prey densities to low levels at which predators simply cannot find enough prey to subsist and reproduce successfully.

"Poaching depresses prey density to levels at which predators cannot subsist."

The prey base on which predators depend also gets destroyed through competition with a rapidly increasing livestock population scourging our protected areas. Cows, buffaloes, goats and sheep are taking over the ranges of the rhino, wild buffalo, gaur, deer, antelopes, wild goats and wild sheep, in ever-increasing numbers. Unlike the wild ungulate communities which have evolved to sustainably use plant resources in their habitats, these introduced domestic livestock overload, modify and damage natural vegetation rapidly, eliminating wild competitors in their original habitats through food-deprivation and contagious diseases. In addition, wild prey species have to contend with damage and disturbance resulting from activities such as the collection of fuel wood, timber and non-timber forest produce by local people and Forestry Departments. Frequent forest fires, lit by people to promote cattle grazing or to facilitate minor forest produce collection, degrade the habitat of the prey. As densities of wild prey decline, the predators are driven to local extinction.

Predators usually show some form of territorial behaviour in which breeding individuals (or groups) actively defend good quality home ranges from other animals of their own species.

"As wild prey-densities decline, predators are driven to local extinction."

Among some predators, neighbouring breeds are animals which are related. Under such circumstances, inbreeding among close relatives is reduced through dispersal movements of sub-adult animals into distant new populations. However, on account of habitat fragmentation and isolation caused by humans, such movement between predator populations is being drastically restricted. Coupled with the fact that predator populations necessarily occur at very low densities (100 square kilometres of prime habitat may hold only 10 tigers as opposed to 5,000 chital), such habitat fragmentation leads to reduced genetic diversity in the population. These potential genetic threats cannot be ignored. Some scientists believe that, in the long run, such bottle-necks in gene flow pose serious threats of extinction by reducing fertility, increasing cub-mortality and by diminishing the adaptability of predator populations to future environmental changes.

If we reflect soberly on all these facts, we begin to see how complex the issue of predator conservation is. There is no way it can be achieved without some interference in each of our individual lifestyles. Essentially this means that the social needs of land: for agriculture and pasture, as well as for the timber, fuel-wood, dairy and meat products, will have to be provided for without further depletion of the meagre four per cent of the land area now remaining in our nature reserves. Can we achieve these goals? We can, if we are clear about a few basic issues at stake.

First of all, we have to recognize that at least in protected habitats set aside for predator conservation, increasing numbers of people, livestock cannot co-exist with predators. It is more logical to adequately rehabilitate such people on 94 per cent of the land area outside the forests, rather than in the six per cent of fast-shrinking wildlife reserve and their immediate surrounds. Only then can biotic pressures be curbed and perpetual conflict avoided. Either people have to be adequately rehabilitated elsewhere, or we have to accept the early extinction of predators, followed by that of many other creatures.

"A small minority of criminals will continue to poach wildlife for personal gain."

Secondly, even if the needs of fuel, timber and fodder of the local people are met through imaginative schemes of land rehabilitation outside protected areas, a small minority of criminals in society will continue to illegally hunt or ravage protected reserves for their immediate gain. Such elements will always have to be stopped with the only language they understand – effective use of force.

Thirdly, wherever predator conservation efforts bear fruit and breeding populations of predators are established, human-predator conflict will follow on the edges of such protected areas. The problem is most acute with big cats in forests, and with wolves on the plains. In such cases, locally surplus predators have to be eliminated through an effective removal program to neutralise peoples' animosity towards problem predators. The focus should be on saving the predator species involved, not on being 'kind' to every individual predator.

Fourthly, having interfered with natural predator-prey systems for over thousands of years by modifying landscapes and habitats, we now cannot afford the populist 'leave nature alone' philosophy of predator preservation. There is an urgent need to accurately monitor how predator and prey populations are responding to natural and man-induced habitat changes, and, to tailor our management practices to achieve the clearly foreseen conservation goals. Such rational wildlife management can only be based on a solid foundation of ecological information collected using acceptable scientific methods. The neglect of wildlife sciences entrenched in our present wildlife management policies should give way to a more enlightened approach.

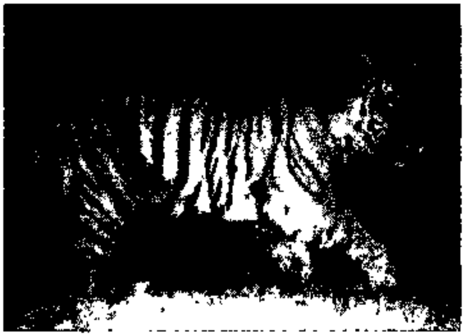
"Since neither predators nor prey can vote, protecting them is going to be tough."

Since predators or their prey can not lobby, agitate or vote to protect their resource needs, ensuring their survival even in the minimum available habitat is going to be tough. Merely parroting sentimental cliches about 'people living in traditional harmony with nature' is not going to help us solve these thorny, real problems. At this critical juncture, effective predator conservation requires strong political commitment on the part of the government. Such commitment has to be backed by environmentalists who should educate the public with hard facts rather than sentimental fiction, about predators, prey, and the balance of nature.

The fennec and the jerboa both have over-developed ears, the former to find prey and the latter to avoid predation. There is a veritable arms race on in nature, with attack and defence being the triggers for evolutionary adaptation.

Annexure

COUNTING TIGERS IN THE WILD: Magic, Art, or Science?



To understand the dynamics of predator and prey it is essential to have some idea of the density of predators a habitat can support. The following piece explains the author's views on current methods of estimating tiger numbers and highlights some unique new ways he has used to great advantage in tiger habitats all over India. This includes the camera traps (see overleaf) with which the tiger (above) took its own picture

Twenty-five years ago, efforts were launched worldwide to save tigers. Most Asian countries harboring wild tigers passed laws to control tiger hunts by sportsmen and establish wildlife sanctuaries in which human intrusions such as farming, grazing, setting fires, and timbering were forbidden. Implementing these laws was another matter however. The burden fell on underpaid forestry services personnel who often did not possess the necessary resources, training, and political backing. Consequently, the tiger's overall decline continued, except in parts of India and Nepal, where half the world's tigers live. There, thanks to disciplined efforts of wildlife managers, backed by political will at the highest levels, several fine reserves were established. At least in these few pockets, tiger populations recovered.

Through the 1980s, while India's reserve managers continued to report dramatic countrywide increases in tiger numbers, IUCN (World Conservation Union) and other conservation agencies were eager for a "success story". Ignoring the warnings of some biologists, they repeated these numbers without hard data to back them up. Recently, when evidence of the horrendous scale of tiger poaching in Asia surfaced, their complacency was shattered. It became clear that the tiger numbers being trumpeted by various Asian governments were practically worthless.

Traditionally, wildlife managers in most Asian countries have guessed at the tiger numbers in their reserves. In Russia, managers scout the countryside after a fresh snowfall, assuming that widely separated sets of tracks belong to different tigers. Indian wildlife managers, untrained in population monitoring methods, make the demonstrably untenable claim that they individually identify every tiger in that vast country (one-third the size of the United States) simply by looking at tiger paws prints lifted from dusty trails. In the absence of reliable monitoring, there is no way of knowing whether efforts to save tigers are succeeding or failing.

As the international conservation community responds with increasing urgency to the tiger crisis, there is a critical need for Asian wildlife managers to use objective, rigorous methods to measure the effectiveness of protective efforts. If not, these efforts are bound to flounder, much like a business enterprise that runs without ever drawing up a balance sheet. Therefore, my research focuses on developing better techniques for counting

The author and an associate set up a camera trap in the forests of Nagarhole in Karnataka.

tigers and for training park managers and biologists in these methods.

At the simplest level, tiger monitoring involves repeatedly walking the forest trails and roads that cats use regularly. Tigers mark their passage by scraping the ground and depositing scats – their "calling cards" for communicating with other tigers. The frequency with which we encounter such signs can yield precise indicators for tracking changes in cat numbers over time. Although these indices do not reveal actual numbers, they do show whether the numbers are declining or increasing.

Because tigers are secretive, nocturnal, and scarce, visually counting them is impossible. Tiger numbers are correlated to the numbers of deer, pigs, wild cattle, and livestock on which they survive. Tigers annually kill about to 10 per cent of available prey, so realistic estimates of tiger populations can be derived from accurate prey counts. In high priority areas, such as special tiger reserves, it may be necessary to estimate population densities of tigers by identifying individuals. But because the paw prints of the same tiger may look different due to variations in soil type, slope, movement, and other factors, prints are not reliable. Shape and arrangement of stripes on tigers are distinct enough, however, for even school children to identify individuals. It is almost sa if the tigers have their names written on their bodies. If clear photographs can be obtained, the animals can be counted accurately.

In Nagarahole, I used commercially available camera traps to count tigers. A camera trap consists of a flash-equipped, autofocus camera wired to an electronic tripping device not unlike those used in burglar alarms. Every evening, I would go to a part of the forest and set the traps across trails frequently used by tigers. While I slept peacefully in camp, the tigers would pad down the trails and, after breaking the invisible electronic beam that triggers the camera, take their own pictures. The resulting portraits helped me to gradually identify their coats/. With the help of statistical analyses, these identifications showed that my study area was packed at a density of 40 tigers per 100 square miles. These numbers tallied perfectly with the tiger densities I had estimated based on prey availability.

K. Ullas Karanth

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