two blackbuck also disappeared for some time, only to reappear with a well developed young.

The next animals to be introduced to the Astroni Park were a pair of sitatunga *Tragelaphus spekei* and a pair of eland *Taurotragus oryx*. This time we wished to establish whether animals that were in poor condition would improve physically in the Park. The eland male (born in the Naples Zoo) had badly shaped hind-quarters owing to poor development, while the eland female (also born in the zoo) had a dry coat and did not appear very healthy. The sitatunga male was injured in one of its hind legs and could only walk on three legs. The sitatunga female was in good condition. All these animals adjusted well to living in the Park, became completely acclimatised and all have bred. The young are in good condition and have developed normally.

For a time a pair of guanaco *Lama guanicoe* and a pair of Himalayan tahr *Hemitragus jemlahicus* were also introduced to the Park, but they were later removed in case they should interfere with the balance that had been established between the species already introduced there.

Given that suitable conditions are available, as in the Astroni Wild Animal Park, it would seem that biologically the creation of wild animal parks presents no difficulty. At Astroni we are planning a Biological Centre to facilitate observations on the animals introduced to the Park and on animals that will be introduced in the future.

I should like to emphasise that all this has been accomplished without modifying the natural appearance of the Park, and without supplying extra food for the animals that live in the Park. At the time of writing (August 1966) there are more than 70 animals living in the Park.

From the success with which the animals have adjusted to living in the environment of the Astroni Park, it is highly probable that animals similar to the species so far introduced would also do well there. Obviously, as the animals increase in numbers, it may be necessary to provide them with extra food. However, this would not invalidate the basic biological suitability of the Park for the animals that have already been introduced there.

A possible reason why no territorial conflicts have developed between the species is that they have to wander throughout the Park in order to find food and shelter, while water is only available in one place. As the result, because they are more mobile than they would be normally, perhaps the territorial instinct has become weaker. But this is by no means certain and many more observations will have to be made. Our interpretations may well be incorrect, for as with all observations on animal behaviour, it is very important to be cautious in drawing conclusions. Nevertheless it can be said that the Astroni Wild Animal Park, though still only in the experimental stage, has so far been completely successful.

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Problems and hazards of chemical restraint in wild animals

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INTRODUCTION

The chemical restraint of free-moving wild animals is a comparatively recent possibility arising out of the development of a projectile syringe. Until a projectile capable of carrying a chemical compound to a selected animal was elaborated (a twist-drill coated with the immobilising compound was used by Hall and associates in 1953), free-moving wild animals could only be subjected to chemical restraint after capture, or through the agency of food and water. The former was used (with or without

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subsequent chemical restraint) for truly wild animals, and the latter for either recalcitrant domestic or captured wild animals that could not be restrained physically. After the elaboration of an effective projectile syringe by Crockford and others in 1958 and its commercial production by the Palmer Chemical Company, it became possible for all those working or interested in capturing wild animals to purchase and use these instruments. Drugs of claimed efficacy became freely available to the general public.

Although very few would try to anaesthetise a cat or dog, and would consider nothing less but the skill of a trained veterinarian sufficient for this purpose, many people innocent of any training in either anaesthesiology or pharmacology, have confidently attempted the far more difficult operation of remote restraint. This is partly because the animals originally subjected to this form of capture were expendable, and partly on account of the tempting similarity between using a syringe projector and a rifle, between chemical capture and hunting.

Wild animals can generally be divided into three broad categories: those that are commonly hunted and regularly killed in large numbers; those that are protected, highly valuable, or rare; and captive animals.

In the first group the use of chemicals is (or should be) limited principally to ethical considerations associated with the infliction of pain or distress. In the second and third categories the monetary or rarity value of the animals becomes an important factor.

The skill and training necessary to restrain a wild animal, whether captive or free, is no less than that needed for the restraint (by tranquilliser or anaesthetic) of a domestic animal of comparable size such as a horse or a cow. In most cases it is more difficult. When chemical capture or restraint, especially of the larger animal, is attempted by persons who have not had the benefit of either basic or specialised training, the resultant mortality is apt to be high.

THE PROBLEMS OF IMMOBILISATION

The problems connected with chemical restraint or immobilisation are similar to those of veterinary anaesthesia except that there are a number of important differences. The subject is unrestrained and usually moving. The distance separating the marksman from the subject is variable, depending on the flight distance or the aggressiveness of the subject. Veterinary anaesthesia is usually preceded by premedication with sedatives or tranquillisers, and parasympatholytic drugs such as atropine or hyoscine. This is not possible when dealing with wild animals, when more than one injection is rarely possible.

Of the various drugs that may be classed as suitable for restraint, a drastic selection must be made in respect of the mode of injection. Only intramuscular or subcutaneous injection is routinely possible. The compounds used have to be extremely potent and concentrated to fit into the capacity of one projectile syringe. They have to be compatible one with another, and of approximately equal speed of action. The muscle masses suitable for injection have to be selected with care. The plane of otherwise suitable areas may not be appropriate for a fast moving projectile syringe, i.e. they have to be approximately vertical to the trajectory.[1] Inadvertent intravenous injection is likely to result in mortality. Injection into tendon, bone, or skin is usually without result so that a syringe is lost and the operator often tempted to raise the dose of a subsequent injection while under the impression that the previous dose was too small.

Following the animal is often very difficult, and it may go down unseen in long grass or thick cover. Under these conditions resuscitating measures are not possible. Some drugs such as Flaxedil necessitate the application of immediate resuscitatory methods if the subject is to survive.

Many drugs disrupt the temperature regulating mechanisms so that hyperthermia results from the fear and excitement, and from unusual solar radiation on the recumbent animal. Dilatation of the pupil and paralysis of the eyelids may result in extensive damage to the eyes. The problems mentioned above are examples of the particular hazards to an animal immobilised under field conditions. Only a thorough knowledge of these factors renders their prevention possible.

It should also be emphasised that much of the reported work on chemical restraint in wild animals using the projectile syringe has been undertaken in open plains or savannah country. When chemical immobilisation is undertaken in thick bush or forest the practical problems are considerably increased. Aiming is more difficult and the syringe itself is

easily deflected by the vegetation, but the principal difficulty is to follow the injected animal. Often the strike cannot be ascertained with certainty before the subject is lost to sight and tracking may be slow and arduous. Where large animals are concerned, the tracking may also be hazardous, and removing for relocation is extremely difficult owing to problems of taking transport into thick country.

POTENTIAL HAZARDS

(a) *Overdosage*

The domestic animal is normally weighed before the injection of anaesthetic compounds. If prior weighing is not possible, an accurate estimation can usually be formed by measurements, palpation and adequate time for consideration. Neither measurements nor palpation are possible when dealing with wild animals; in a free condition they may often only be glimpsed in tall grass or in the bush. Under these circumstances it is easy to make a 100 per cent error in the estimation of the body weight.

The injections are made from a distance which may be 50 to 70 m. The susceptibility of a syringe to deflection by wind or leaves, or the inherent inaccuracies such as differences in loading of the caps used to propel the syringe, may result in injecting another animal. It is regrettably easy just to miss the animal aimed at and the syringe, passing closely over its back, may hit a smaller animal or calf on the far side. If this occurs the outcome is likely to be fatal unless a drug of wide tolerance value is used, and unless it has an effective antidote.

The dosage of drugs follows no definite, unalterable rule and animals differ greatly one from another in their susceptibility to drugs; this problem is overcome in ordinary practice by adequate physical restraint and intravenous injection. The action of drugs administered intravenously is almost instantaneous, and during the injection the animal's reflexes are constantly monitored. Thus, although a complete dose is put into a syringe, the injection can be stopped at any time if the animal becomes sufficiently influenced by a part of the full dose. This is not possible if the full injection is administered intramuscularly. Castration operations on young male cats are usually performed by injecting a carefully computed dose of pentabarbital sodium into the peritoneal cavity of the patient previously deprived of food and drink. In spite of accurate weighing and consequent exact computation of the dose, and although the peritoneal route is more reliable than the intramuscular one, a considerable proportion of the injected animals fail to become anaesthetised and others become alarmingly deeply anaesthetised. Experience may sometimes assist in predicting which animals are likely to require relatively higher or lower dosage rates.

Over-dosage of paralysing drugs is likely to be a particular hazard. This is because the breathing stops due to the paralysis of the respiratory musculature, such as the intercostal muscles and the diaphragm. If this occurs, death from asphyxiation follows in a few minutes, particularly as effective artificial respiration on large animals is highly problematical. When centrally-acting drugs are used the time available for resuscitatory measures is considerably greater. But unless compounds are used that can be antagonised, death may still ultimately result.

(b) *The immobilised animal*

If immobilisation occurs as the result of an injection, only part of the object has been achieved. Still remaining is the health and comfort of the immobilised animal and the task of resuscitation. Many animals suffer postural damage while immobilised. Damage may readily occur to the eyes and limbs. Ruminants tend to regurgitate, and very large animals suffer death from pressure of the intestinal contents on the diaphragm. Regurgitation in ruminants may be almost instantaneously fatal as the animal will inhale its ruminal contents. When not immediately fatal, death will almost certainly result later from aspiration pneumonia.

Bloat is another complication to which ruminants are prone and which is likely to occur with rapidity while lying in lateral recumbency, and which may become so persistent that it is not relieved by placing in sternal recumbency or by pressure on the flank. There are several methods of relieving bloat, of which the passage of a probang or stomach tube is probably the best. The generally advocated method of puncture of the rumen through the abdominal wall should only be used as a last resort and when other methods have failed. Very large animals may suffer respiratory embarrassment due to the pressure of the

intestinal contents on the diaphragm. This may or may not be accompanied by a degree of bloating due to a collection of gases in the colon and caecum. Elephants will die if they fall in sternal recumbency unless pulled over on to their sides. (Pienaar *et al.*, 1966.)

(c) *Possible complications*

(i) Respiratory insufficiency is one of the major complicating factors. Insufficient intake of air is apt to cause a central anoxia which in turn will reduce the activity of the respiratory centre. Central depression will result in coma followed by death.

Adequate respiration may be further hampered by collection of mucous in the throat or the bronchial passages, while the strength of the respiratory drive is inadequate to expel this by coughing. The sensitivity to anoxia or carbon dioxide build-up may be reduced by the chemical compounds used, so that the desire to breathe becomes less.

(ii) Hypotension or a precipitous fall in blood pressure may be induced by certain chemical compounds, and if prolonged can lead to lung oedema, circulatory anoxaemia and death. Hypotension may be caused by the immobilising compounds themselves, by a release of histamine in response to drugs such as curare, or by the incorrect use of the antidotes, such as neostigmine methylsulphate. Depolarising neuromuscular blocking agents such as succinylcholine can cause marked fluctuations in the blood pressure, cardiac irregularities and damage.

(iii) Shock is a complication that can emanate from a number of factors including prolonged hypotension. Unless treated rapidly it results in an increased circulation time, decreased venous return and cardiac output, stagnant and anoxaemic anoxia, capillary damage with loss of circulatory fluid, increased blood viscosity, reduced circulatory volume and eventual central anoxia, circulatory collapse and death.

(d) *Idiosyncrasy*

This is a special and unusual reaction to drugs, usually of an individual. The reaction may be of the allergic type manifested by histamine release or by reactions such as spasm of the muscles of the thorax.

Some species may react badly to drugs which are suitable for others. For instance, because of their low plasma pseudocholinesterase, African buffaloes *Syncerus caffer* will take only about 1/10th of the dose of succinylcholine per unit of body weight as compared to other animals such as Thomson's gazelle *Gazella thomsonii*. The reaction of the various animals to a drug such as succinylcholine is difficult to foretell.

Some groups of animals show few side effects to injection of the morphine-like compounds such as Etorphine hydrochloride (M. 99). Others (such as the horse) show fluctuations in the blood pressure and tachycardia. Morphine depresses the central nervous system of the dog but is predominantly exciting to the cat. In the same way some antelope react to morphine-like compounds by depression, and others by excitement.

Differences in dosage rates of various species have been mentioned. Curious but unexpected similarity can also occur. A zebra weighing 200 kg, and a male White rhinoceros *Diceros simus* weighing over 2,000 kg can both be caught with the injection of 1 mg Etorphine hydrochloride (Harthoorn 1966a).

(e) *Diseases*

The presence of sub-clinical diseases in wild animals is a major cause of loss. The field is too vast to discuss even superficially, but a few examples may be given.

Trypanosomiasis, to which animals may be premune, is apt to manifest itself after capture and result in death if untreated. Fascioliasis has resulted in a massive death rate in captured giraffes, as have other liver parasites. Various internal parasites have caused death in young elephants, captured with or without drugs.

Muscular dystrophy, first reported in East Africa by Jarrett and others in 1964 and 1967 as the cause of death in Hunter's antelope *Damaliscus hunteri* captured by chasing and roping, has since been found to be widespread in wild animals (Mugera and Wandera, 1967). This condition is thought to have been responsible for deaths of giraffes captured during conditions of drought elsewhere.

(f) *Drugs*

Great care has to be exercised when using drugs, especially in the quantity needed to immobilise animals larger than man. Inadvertent injection of

large doses is highly dangerous. Some drugs recommended for restraint such as nicotine alkaloids have caused death after they had contaminated the unbroken skin.

Careful training in the storage and handling of drugs is essential, as is a knowledge of the pharmacological effects, and the side effects.

Small errors in handling, such as change in pH, can result in the chemicals becoming inactivated, resulting in irregular, or absence of, results. This phenomenon has been known to induce an increase in dosage rates with deaths when a new batch of drugs became available. Mixing of different drugs may result in mutual cancellation, or relative inactivation. Some drugs such as succinylcholine have no antidote, and cause death by respiratory paralysis and asphyxiation if inadvertently injected in overdose. Some new successful modern drugs are of unprecedented strength. A few milligrams only of Etorphine hydrochloride are sufficient to immobilise a 4,000 kg elephant, a potency equalled by very few chemical substances.

SAFETY OF PERSONNEL

The safety of the workers employed to capture animals is an important aspect of field work. As in veterinary work, safety is closely linked with the knowledge of the ways and reactions of the type of animal that is being caught, together with the necessary experience of the extent of control exercised by the drugs used.

Even small animals may become highly dangerous if captured or cornered.

Some animals are normally dangerous if improperly restrained. Among these are elephant and hippopotamus and antelope such as oryx. Individuals of a species such as giraffe may show surprising reactions (Harthoorn, 1963b).

DISCUSSION

The various graduations between immobilisation and tranquillisation and the related degree of incapacitation and therefore safety can only be judged from experience. Under suitably adjusted states of neuroleptic narcosis, large standing wild animals such as the rhinoceros and elephant may be handled and even mounted, and medium sized animals such as wildebeest or zebra led for considerable distances subjected to manipulations such as blood pressure measurements, or rectal examination (King and Klingel, 1965).

With the use of compounds such as Etorphine hydrochloride (Bentley and Hardy, 1963) recently adapted for large animal restraint (Harthoorn, 1963a) the degree of safety of wild animal immobilisation has increased tremendously. The complications have also increased so that the methods cannot be said to have become easier in practice.

A veterinary training is of great advantage as a basis for work with wild animal immobilisation, as it makes the training period shorter, and the details easier to assimilate. For non-veterinarians the training is more difficult, but not impossible to acquire.

An example of a highly successful operation carried out largely by non-veterinarians is the now classic Zululand White rhinoceros operation, in which well over 400 rhinoceroses have now been moved with drug deaths or non-recovery from immobilisation of under 1 per cent. Although this operation began with the team working together with a veterinarian experienced in large wild animal restraint, it has largely been carried out by the team of rangers working alone, and the success is due to their hard work, enthusiasm and devotion to their task. Other operations, such as the extensive work done in the Kruger National Park, were both initiated and continued with veterinary advice and participation (Pienaar *et al.*, 1966a and 1966b). More recently, work in Kenya, initiated by veterinary participation (Harthoorn, 1966b), is continuing on a sound footing (Russell, 1967). In other instances immobilising operations, started without the benefit of extra advice and training, have resulted in complete failure.

The immobilisation of wild animals is expensive in drugs, syringes and transport. Experience dictates that the greatest success in the immobilisation of wild animals has been met when an experienced instructor has been obtained. It is seldom realised that the travel expenses involved in procuring such skilled help are equated by the value of even a few animals, which might otherwise have been lost.

FOOTNOTE

For further details of modern developments in immobilising compounds see the following publications:

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Flaxedil is a sedative and is manufactured by May & Baker Ltd, Dagenham, Great Britain.

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