and what is safe for one animal will be toxic and even lethal for a similar animal of the same species. Great skill and experience is required in the use of paralytics, and ideally they should only be used by a veterinarian.

Table IV, on page 322, is a summary of the remarks made by zoological collections all over the world in response to the questionnaire mentioned above. Also included is a detailed list of dosage rates of tranquillizer and paralytic drugs compiled from information supplied by the zoos that helped in the survey. Following that table, there is a summary of some of the cases upon which a variety of tranquillizers have been used in the animal hospital of the Zoological Society of London.

METHODS OF CONTROL OF WILD ANIMALS WITH THE USE OF DRUGS, WITH SPECIAL REFERENCE TO THERAPEUTIC AND VETERINARY ASPECTS

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INTRODUCTION

The technique of control of wild animals in the actual sense of handling is essential for their protection and welfare. There are virtually no sanctuaries left in the world which are large enough to allow large wild animals a truly natural existence and to find a completely natural balance between predator, herbivore and environment. Where the area is restricted the degree of management must increase in inverse proportion. Where the space is small, interference must include not only maintenance of a balance between the species and environment, but also direct interference with, or assistance to, the animals themselves. This is extended to its logical conclusion in Zoological Gardens where the individual animal may be of great value and necessary veterinary assistance is not only a desideratum but a moral obligation.

When the animals are kept in close confinement, the performance of drug immobilization is essentially the province of the veterinarian. It is a method of rendering the animal susceptible to handling and the administration, either of other drugs to induce anaesthesia as a preliminary to extensive surgical interference, or else to minor manipulation with or without local anaesthesia, or even for vaccination, removal of foreign bodies from eye or throat, or any of the multitude of smaller attentions ranging from the diagnosis of disease to the paring of hooves. In free-running animals, the technique of immobilization is also a valuable tool for the ecologist.

The term *immobilization* is used to describe the incapacitation or paralysis of an animal with a drug, or drugs. To the free-roaming animal these are delivered in a projectile syringe. The captive animal lends itself to a wider choice of methods to render him tractable. These may range from tranquillization to anaesthetization, and the drugs may be administered in food, or by hand injection or even inhalation. In many instances a combination of these methods may be used and, in our experience, many techniques may be suitably introduced by the preliminary administration of drugs such as chloral hydrate or tranquillizers by mouth, given in food or drink. Muscle-relaxant drugs or neuromuscular blocking agents need not be given as far as the stage of complete paralysis. If the paralysing dose and the body weight of the animal are known, a sub-paralysing dose will weaken strong and usually intractable animals. In this way, using a full dose of chlorpromazine hydrochloride followed by two-thirds of a paralysing dose of gallamine triethiodide, we have been able to transfer fully grown male buffalo (*Syncerus caffer caffer*), body weight about 1,400 lb. into vehicles, using only one rope and a few men. On other occasions free-roaming animals such as giraffe (*Giraffa*

camelopardalis rothschildi) body weight 1,700 to 2,200 lb., have been caught with gallamine triethiodide, administered in a projectile syringe, and then anaesthetized with intravenously administered chloral hydrate for physiological experiment and observation. In the Game Department Zoo at Entebbe, the immobilization of antelope such as water buck (*Kobus defassa ugandae*) using muscle-relaxant drugs and a projectile syringe has been found the only practicable method for catching these animals in their large paddocks, which are natural areas and unequipped with night quarters. The method of drug immobilization has also been used in the National Parks for therapeutic interference in free-roaming wild animals, for example the examination of a lame bull elephant (*Loxodonta africana*), estimated body weight 9,500 lb., with a view to surgical interference and the administration of antibiotics.

HISTORICAL

A method of immobilizing free-roaming, white-tailed deer was first published by Hall, Taft and Aub in 1953; the immobilization of giraffe has been described by Goetz and Budtz-Olsen in 1955 and further work was done by Crockford, Frank, Hayes, Jenkins and Feurt (1957 a & b), and improvements effected by the development of an automatic projectile syringe, Crockford *et al.* (1958). The use of Flaxedil for captive elk (Wapiti) was described by Post (1959). Succinylcholine was successfully used on various large captive felidae by Pistey and Wright in 1959, and on trapped grizzly bears by Craighead, Hornocker, Woodgerd and Craighead in 1960. A large number of captive species have been successfully immobilized with the use of succinylcholine by Thomas (1961). More recently, a reversion to the solid dart, with nicotine applied as an effervescent paste, is described by Montgomery (1961).

MATERIALS USED

(*a*) *Drugs.* Successful immobilization of a number of animals has been achieved using three muscle-relaxing drugs: *viz.*, succinylcholine (suxamethonium) chloride, d-tubercurarine chloride, and gallamine triethiodide. These are neuromuscular blocking agents and block the transmission of the nerve impulse at the neuromuscular junction; the place where the nerve and muscle join. They do not all act in an entirely similar way. Succinylcholine blocks the nerve impulse by causing a persistent depolarization of the muscle-end plates although it has other subsidiary actions as well. Gallamine triethiodide and tubercurarine chloride reduce the muscle-end-plate potential, so blocking the normal physiological action of acetycholine. The effect of all three is on voluntary muscle. It should be remembered that the muscles of respiration fall into this class and that these are affected by doses sufficient to cause locomotor paralysis. The pattern of respiration is altered, by increasing action of the abdominal muscles and decreasing thoracic respiration. Where excessive doses have been given, voluntary respiration will cease and artificial respiration must be resorted to. Where gross excess is given, vasomotor disturbance with blood pressure changes may result. An excess given to the ruminant will tend to induce regurgitation of the ruminal contents, with death due to inhalation of water and solid matter.

The advantage of using drugs such as tubercurarine and gallamine is that the action may be largely reversed with the use of an antidote. The most satisfactory is neostigmine methylsulphate. It should be remembered, however, that as well as its anti-curare effect, it has also a parasympathetic stimulator action, and tends especially to increase salivary and bronchial secretion. Given in excess it has a paralysing effect and may also cause vasomotor disturbance. The vagal effects of neostigmine may be prevented with atropine, and atropine sulphate is most conveniently added to the primary immobilizing solution. Atropine is also a necessary adjunct to the use of succinylcholine for some animals.

Besides the muscle-relaxants reported here, extensive use has been made of chlorpromazine hydrochloride ('Largactil' May and Baker). This has been used on all animals which have been extensively

handled or transported after capture. It has been found more suitable than many other ataractic drugs largely because it also has a soporific effect which is of advantage in conditioning newly caught animals. It has been given as a routine to animals destined for transport, both on capture, and again when taken from their temporary holding ground to more permanent habitation or release. Dosages range from one milligram per pound body weight for antelope to only 0.125 for fully-grown giraffe.

(*b*) *Syringes.* The syringe used was basically the projectile syringe supplied by the Palmer Chemical Co, Inc., (Atlanta, Georgia). For field work it was found necessary to redesign the activating mechanism and this, together with details of the instruments of propulsion, will be described elsewhere (Harthoorn & Lock, 1961a). For distances up to 40yds. with medium-sized animals, the standard projectile syringe and also the carbon dioxide-powered gun as supplied by the Palmer Chemical Company is adequate. Where the flight distance of the animals dictates, modified syringes are propelled by a cross-bow or by a powder-charged gun to cover distances of 60 to 100 yds.

METHODS

(*a*) *Free Roaming Animals.* In the case of antelope, buffalo and giraffe, these are usually approached in a Land Rover and the syringe fired either from a camouflaged position in the back, or from the cab. Other animals, such as rhinoceros and elephant are mostly approached on foot. The syringe contains the immobilizing drug or drug mixture, according to the species of the animal. After firing the syringe, the animal is watched from the vehicle with field glasses or followed if necessary, till it goes down. It is then approached in the method found most practicable and ear tagged, measured, or tied and tranquillized according to the purpose of the capture.

(*b*) *Captive Animals.* When these are in large enclosures, the method is basically the same as for free-roaming animals. Where they are in close confinement a different procedure is followed. This usually consists of (*i*) preliminary feeding of tranquillizer or soporific in food. (*ii*) catching, usually by securing with a rope. (*iii*) administration of tranquillizer. (*iv*) administration of muscle-relaxant if required.

RESULTS*

The administration of tranquillizer for animal transport has been a uniform success. Thirteen kob antelope (*Adenota kob thomasi*) were transported 340 miles to a game reserve without fatality. Largactil at a rate of one mgm./lb. body weight was used. Largactil was also successfully used for transporting thirty black rhinoceros and has also been used without fatality on a number of giraffe and zebra.

The results of the use of muscle-relaxants may be considered under two headings.

(*a*) *Results on Medium-sized Antelope*

(Summary)

The development of safe immobilizing techniques for the medium-sized antelope was relatively simple. Fifty male kob antelope (*Adenota kob thomasi*) have been immobilized in the Semeliki valley in Western Uganda, without loss (Buechner, Harthoorn & Lock, 1960). The purpose of this exercise was to mark a number of males for a study of their territorial behaviour (Buechner, 1961). The drug used was succinylcholine chloride (suxamethonium chloride) which appears to be a safe and efficient drug for this type of animal. The injection and drug cause very little distress to the animal and no increased fear of man is evinced by recently immobilized antelope as long as certain precautions are observed. These are (*a*) A silent approach to the recumbent animal, preferably out of his line of sight. (*b*) The blindfolding of the animal with a hat or cloth over the eye while measurement and other observations are made. (*c*) No talking within earshot and (*d*) Retirement to 30 yds. or more during the recovery phase.

*Taken in part from Harthoorn & Lock (1961b).

A pilot experiment to move kob antelope from farmland as an alternative to shooting was made in March 1960. More than thirty female kob were immobilized, many of them in advanced pregnancy. The immobilization was effected almost entirely by the game warden, showing that, for some species, the immobilizing method can be considered as a practicable tool for animal preservation. This year a similar exercise involving large numbers of kob was successfully carried out. A dozen animals of two other species, the hartebeest (*Alcelaphus lelwel jacksoni*) and waterbuck (*Kobus defassa ugandae*), have also been immobilized using succinylcholine and without loss. Gallamine triethiodide has also been used on these animals without mortality but has the disadvantage of longer reaction time with a greater chance of loss of the animal in bush. Immobilizing techniques for other medium-sized antelope have also been evolved (Talbot and Lamprey 1961).

(*b*) *Results on the Larger Mammals*

1. *Hippopotamus* (*Hippopotamus amphibius*),

In the course of the last year, twenty-three of these animals were injected with succinylcholine; some of these got into shallow water before becoming immobilized without apparent harm. Two of these did not recover from the immobilizing dose. Two more were immobilized with gallamine triethiodide, taking in the region of 1.8 mgm./lb. body weight.

The dose of succinylcholine used was 0.08 mgm. per pound estimated body weight. Of the two that failed to recover one received a frank over-dosage due to an over-estimation of its size, and the other on closer inspection proved to be a most debilitated subject.

Succinylcholine appears to have advantages over gallamine triethiodide for immobilizing the hippopotamus, especially as very much larger quantities of the latter are necessary, and it takes longer to take effect. Gallamine is possibly safer and might be the drug of choice when the animals are of high value, or in a restricted area.

2. *Buffalo* (*Syncerus caffer*). Six buffalo have been immobilized with gallamine triethiodide without loss, and four with d-tubercurarine with the loss of the first. The addition of atropine to the tubercurarine solution would almost certainly have prevented its death which occured 1½ hours after it went down and when it was apparently almost recovered. Histamine release and its effect on the bronchi cannot be ruled out. The dose of gallamine triethiodide used was 1.2 mgm. to 1.3 mgm. per pound body weight. Average time to go down was 11 minutes.

3. *Giraffe* (*Giraffa camelopardalis*). Eight giraffe have been immobilized with gallamine triethiodide without loss. Two of these were done in Kenya and the remainder in Uganda. Two of the latter were killed after recovery for reasons unconnected with the immobilization. The weights and dosage were as follows:

   Female, body weight 2,002 lb. dose 0.87 mgm./lb. Down in 35 minutes.

   Female, body weight 1,100 lb. dose 1.6 mgm./lb. (partly subcutaneous). Down in 85 minutes.

Three young giraffe were captured for transport with doses estimated at 2 mgm./lb. body weight. These animals will eventually be weighed, after which a more exact rate of drug administration can be given. A large female giraffe which was given a dose probably in the region of 2.5 mgm./lb. went down in 10 minutes. It appears that this drug can be used with complete safety for the capture of giraffe and with an optimum dosage rate in the region of 1.7 mgm./lb.

4. *Rhinoceros* (*Diceros bicornis*). Ten rhinoceros have been immobilized with gallamine triethiodide, one of which did not recover from the immobilizing drug (No. 9) and one died soon after recovery (No. 10). The first eight were immobilized without loss. The first four were immobilized by us at Kariba (Harthoorn & Lock, 1960), and the next three by the Southern Rhodesian Department of Game using the same drug mixture (Child, 1960). Nos. 8, 9 and 10 were immobilized in East Africa.

No. 9 was darted twice and death was probably due to insufficiently rapid administration of antidote. No. 10 was left alone after recovery for 30 minutes while a search was made for the other half of our party, and probably absorbed more drug. A little more neostigmine would almost certainly have ensured his recovery.

Dosage rates were as follows: In Rhodesia: 0.6 mgm.–0.75 mgm. per estimated pound body weight proved sufficient to cause immobilization. In East Africa: 0.8–0.9 mgm. per estimated pound body weight was necessary.

The rhinoceros, which are darted in a hunting area, run with such determination that smaller doses will fail to bring them down within five or seven miles – if at all. The rhinoceros outside reserves is heavily and continuously poached for the value of its horn, and is the only one among the species mentioned here that will run far on being disturbed. (Antelope will usually run no more than 100 yds. on feeling the injection.) The technique breaks down on the inability to follow the animal rapidly through rough country so as to reach him in time to administer neostigmine, rather than a failure of the immobilizing technique.

While drug-dosage has been ascertained that will allow immobilization of larger animals such as giraffe, buffalo, hippopotamus and elephant with negligible or no mortality, the rhinoceros still presents a formidable problem. This is doubly unfortunate as the elucidation of suitable methods of immobilization of that animal, especially for translocation, is the most urgent. Its marked divergence from the reaction pattern of other animals to neuromuscular blocking agents makes laboratory experimentation of only limited value.*

5. *Elephant* (*Loxodonta africana*). Seven elephant have been immobilized with gallamine triethiodide and four of these marked. One did not recover from the immobilizing dose. One was shot 20 hours later due to its inability to extricate itself from mud.

It is pertinent to mention here that the movement of elephant in Uganda is a great problem and the destruction of considerable numbers is envisaged here and in Kenya by controlled cropping. A detailed study of elephant movements is urgent and marking essential for this purpose. (Harthoorn, Lock and Luck, 1961). From the pattern of immobilization with the muscle-relaxant drug, it is expected that fatalities as a result of the capture for marking of elephan will be very small.

It may be interesting to give the elephant dosage in slightly greater detail as follows:

TABLE †

No.	*Sex*	*Estimated dose*	*Result*
1	Male	0·9 mgm./lb.	Immobilized, but remained on feet, recovered in 30 min.
2	Male	1·6 mgm./lb.	Died 2½ hours after going down.
3	Female	1·1 mgm./lb.	Immobilized but remained on feet, helped by her friends.
4	Male	1·2 mgm./lb.	Down, marked, recovered.
5	Female	1·3 mgm./lb.	Down, recovered, destroyed after 20 hrs.
6	Female	1·2 mgm./lb.	Down, marked, recovered.
7	Female	1·2 mgm./lb.	Down, marked, recovered.

No. 7 went down in 20 minutes, was given antidote 15 minutes later, and rose in 10 minutes.

The dosage rate cannot be vouched for till a much larger series has been completed. This is to be undertaken shortly at the request of the Uganda Department of Game and Fisheries which is anxious to mark a number of these animals to determine their movement pattern.

DISCUSSION

The use of muscle-relaxant drugs is still in an experimental stage and the mortalities suffered should not be considered as an inevitable percentage of continued loss. Little work has as yet been done and only over a short period of time. The elaboration of sound and safe techniques is hampered by the considerable difference between the reaction of laboratory

*Since writing, a suitable and safe drug mixture has been elaborated and twelve rhinoceros immobilized successfully with its use.

†Taken in part from Harthoorn, Lock & Luck (1961).

animals and the large species such as rhinoceros and giraffe.

The technique can already be considered as a tool for certain species – such as for kob antelope to remove them from farmland – so that the method may be applied by relatively untrained people and with an expectation of no, or negligible, mortality. A survival rate of near 100 per cent can be expected if accurate weight judging can be accomplished and a number of precautions are observed. The use of antidotes such as neostigmine requires, in some cases, more skill than the use of the muscle-relaxant drug, and the person handling these large animals should be conversant with treatment for shock, expecially the simple technique of saline infusion and saline combined with a vasoconstrictor such as noradrenaline. Gallamine is eliminated principally by excretion through the kidneys and the state of hydration of the animal is probably of considerable importance.

A number of other factors should also be taken into consideration. Large elephants which do not normally lie down on a horizontal surface are bad subjects for immobilization unless methods are at hand for assisting them to the upright position. The temperature of the animal tends to rise before relaxation occurs, and the use of certain relaxants may be inadvisable during very hot weather. The safe dose of neostigmine varies for different species and pending further work on this problem, a dosage rate of one milligram per 100 lb. should not be exceeded for any one injection. Lastly, a number of reports reveal dosage rates for animals in Zoological Gardens, which seem to differ markedly from those we found needed by free roaming wild animals. Although most of these dosages are unconfirmed, it may be well to proceed on captive animals with caution in case various factors in their existence render them less resistant to ataractic or paralysing drugs.

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