ADDENDA

Crex egregia

Add to footnote to Table 1 (*a*) the following references: Rudebeck (*S.A. Animal Life, Aves I*, 1955) and Clancey (pers. comm.).

In the Central African Museum (formerly Congo Museum), Tervuren, there are thirteen Katanga specimens, from Kasaji and Kolwezi: December 4, January 1, February 2, March 4, April 2 (Dr. H. Schouteden, pers. comm.). The Northern Rhodesian specimen in the table for November is actually in the Rhodes-Livingstone Museum, wherein there are three others from the territory (not in the table), two for January and another for November. This last was found by R. C. Hart, freshly killed against a wall at Hillside School, Livingstone, at 06.00 hrs., 25th November, 1963. It was a male, with both testes 10 × 5 mm.

Friedmann (in Strong, *Afr. Repub. Liberia & Belg. Congo*, 2, 1930: 751) reports a specimen collected 15 or 20 miles off shore near Loango, ex-French Congo, 29th November.

Sneyd Taylor (*Ostrich*, 1952: 167) records seeing one at Fort Beaufort, Cape Province between 20th August and 26th November. This was probably an odd individual which had failed to migrate. Farkas (*Ostrich*, suppl. 4, 1962: 25) seems to accept the species as resident at Barberspan, and Courtenay-Latimer (*Ostrich*, 33 (3), 1962: 38) lists it as so for the Gonubie Bird Sanctuary. This needs further investigation.

Perdana marginalis

Add two more Katanga specimens in Table 1 (*b*), one from the Upemba National Park for January (Verheyen, 1953), and one in the Central African Museum from Elizabethville, 3rd January (Schouteden, pers. comm.).

Of the two records from the Republic of South Africa, the Durban specimen was collected on Greyville Racecourse by A. D. Millar in March, 1905 (Clancey, pers. comm.). The other specimen, from East London, in the South Africa Museum, bears no date (Winterbottom, pers. comm.), though it was presumably this specimen which was collected in May (Stark & Sclater, *Birds S. Afr.*, 4, 1906).

For another breeding record from north of the equator, see Lamm & Horwood (*Ibis*, 1958: 175).

Ceyx picta

Dated specimens of *madagascariensis* in the Central African Museum from Ruanda, in addition to that from Kirinda, are: Cyangara, 7th August and Kisenyi, July (Schouteden, pers. comm.).

Halcyon senegaloides

In regard to the specimen attributed to *cyanoleuca*, collected by Boyd Alexander on the Shari River on 18th June, 1905, from a perusal of his *From the Niger to the Nile*, 1907 (see especially Vol. 2: 148), it would appear that on this date he was some forty miles up this river from Fort Lamy, that is, at approximately 11° 36′ N., 15° 12′ E. This is much further north-west than any of the other specimens attributed to *cyanoleuca* from north of the equator, and the identification must therefore be regarded with particular reservation.

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GAME ELIMINATION AS A MEANS OF TSETSE CONTROL WITH SPECIAL REFERENCE TO HOST PREFERENCES

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INTRODUCTION

GAME elimination as a means of controlling the tsetse fly has for many years been a topic of some controversy. The public has, quite rightly, felt strongly over the elimination of the indigenous fauna of African territories although the arguments submitted against game elimination have not always been particularly sound.

The theory behind game elimination is simple. Tsetse flies feed almost solely on the blood of game animals, at least in the case of *Glossina morsitans*, the commonest of the Rhodesian species. If the game animals are eliminated from a fly infested area and that area is subsequently maintained free of game then the fly will be unable to live there. Also, game animals provide a reservoir of trypanosomiasis which can infect cattle via the agency of the tsetse fly and possibly other biting flies. In addition game animals carry other diseases transmittable to domestic stock and elimination can be further justified on these grounds. The success of this method of tsetse control has been well demonstrated in Southern Rhodesia as described by Chorley (1917) and Burton (1955), and it is interesting to note that it is in that country that adverse public feeling has been greatest. However in Southern Rhodesia the fly is near the southern extent of its distribution, occupying relatively high and cool ground, so that it lives close to its lower temperature limit. Under these conditions it may be that extermination of the fly is easier than in hotter climates. In addition game elimination is likely to be easier to carry out in the more open woodland, dominated by species of *Brachystegia* and *Julbernardia*, characteristic of much of the plateau country of Southern Rhodesia, than in the thicker bush in which *G. morsitans* is recorded in some other parts of Africa. Game elimination has also been exercised in eastern Africa but the results have generally not been so clear cut, not necessarily because successful control of the fly was not achieved but because this method of control was often employed side by side with others such as bush clearing and the use of insecticides.

It must, however, be accepted that the theoretical value of game elimination as a means of controlling *G. morsitans* has been proved in practice.

Game elimination, if it is to be successful, is a lengthy process extending over many years and, apart from the repugnance which must be felt at the thought of the destruction of the indigenous fauna, the costs are likely to be high, so that all efforts should be made to ensure that the most effective use is made of this method.

When considering any game elimination scheme already in progress it is profitable to ask two questions:

(1) Are sufficient numbers of animals being removed from the area to ensure that elimination is achieved within the required number of years? Complete elimination is not necessary for effective tsetse control but experience has shown that the game population must be reduced to a very low level. Unless the number of animals shot each year, plus the numbers which migrate out of the area in question, together with those which die natural deaths, is greater than the rate of natural replacement by birth and inward migration, then the scheme is of little value. It must also be borne in mind that as an animal population is reduced below the maximum number possible in a given habitat then the rate of natural increase becomes greater. The growth of an animal population, if numbers are plotted against time, shows a sigmoid curve. This is because the increase in numbers is least when the population is small and also when it is approaching its maximum, and at its greatest midway between these positions. Visualising such a sigmoid curve with the number of game animals in a given area near the top of this curve then the introduction of a game elimination scheme will initially reduce the numbers to a central position on the curve where the rate of increase is greatest. If insufficient animals are shot, whether this be due to inefficiency of the hunters, their scarcity on the ground or to other factors, then little may result apart from a slight reduction in numbers of animals and a lowering of their mean ages.

(2) Are the right animals being shot? Research work has shown that each species of tsetse fly has definite "preferences" for certain host animals on which to feed. If game elimination is to be successful it must aim at eliminating those species which are the preferred hosts and not waste time on hunting those species which are of little significance as a food supply for the fly. It should also be remembered that host "preferences" may perforce be altered if a normally "preferred" species is reduced greatly in numbers, particularly in the case of *G. morsitans* which feeds on a wide range of hosts.

This paper poses the latter question, and deals with a game elimination scheme which has been in progress for many years in the Fort Jameson District of Northern Rhodesia.

Game Elimination and Tsetse Host Preferences—Fort Jameson

A game elimination scheme has been in progress in the Fort Jameson District for many years but this paper only considers the period 1956–61. It was during this period that a study of the host preferences of the tsetse fly (*Glossina morsitans*) took place.

The scheme has been worked in conjunction with discriminative bush clearing and in 1961 with insecticidal applications. Success achieved in controlling the fly cannot therefore be attributed to game elimination alone. All control operations have taken place along the periphery of the vast eastern fly belt where this comes into close proximity with the cattle areas of the Fort Jameson District. The numbers of game animals shot during the period 1956–61 are shown in Table 1. This table requires some explanation:

(*a*) only certain species were hunted throughout the whole period under consideration, these being buffalo, eland, kudu, roan, warthog, bushpig, sable, waterbuck and impala.

(*b*) The hunting of duiker only commenced in 1959. Prior to this it was not considered to be a potential tsetse host of any great significance largely because of its small size and the results of investigations made by Weitz & Glasgow (1956) concerning the host preferences of tsetse flies. In 1959 the hunting of duiker was undertaken in certain sectors of the tsetse periphery where it appeared to be by far the most common game animal. The hunting of other smaller species, namely oribi, bushbuck, reedbuck and grysbok commenced in 1960, 1959, 1959 and 1961 respectively.

(*c*) Hunters employed on this scheme have occasionally shot elephant throughout the whole period but generally this was a deterrent against garden raiding rather than as a tsetse control measure. Elephants shot from 1959 onwards as shown in Table 1 were shot as part of the tsetse control programme.

(*d*) The hunting of hartebeest and zebra ceased in 1959 as a result of the findings of Weitz & Glasgow mentioned below.

(*e*) In addition to those species listed in the table, baboons and monkeys were shot in large numbers up until the end of 1958 but this was looked upon as being vermin control rather than a tsetse control measure.

TABLE 1

Animals Shot on Tsetse Control in Fort Jameson District 1956–61

Species	1956	1957	1958	1959	1960	1961	Totals
Buffalo	51	46	57	58	27	28	267
Eland	20	31	26	36	12	8	133
Kudu	45	36	40	76	81	65	343
Roan	26	23	61	66	52	51	279
Sable	9	15	2	—	1	1	28
Waterbuck	—	—	1	—	1	—	2
Hartebeest	8	21	25	17	—	—	71
Reedbuck	—	—	—	1	8	7	16
Bushbuck	—	—	—	10	40	24	74
Impala	1	2	—	5	—	—	8
Duiker	—	—	—	40	133	210	383
Oribi	—	—	—	—	2	4	6
Grysbok	—	—	—	—	—	3	3
Warthog	57	100	139	186	97	112	691
Bushpig	24	41	58	97	68	41	329
Elephant	—	—	—	7	16	33	56
Rhinoceros	—	—	—	—	1	—	1
Zebra	13	27	20	26	—	—	86
Totals	254	342	429	625	539	587	2,776

Until Weitz & Glasgow (1956) published their paper little was definitely known about the host preferences of tsetse flies. Their findings, based on the analysis of blood meal samples collected from tsetse flies caught in several East African territories and also Southern Rhodesia, indicated that *G. morsitans* feeds predominantly upon warthog. In addition, a further twenty-two hosts were recorded with the striking absence of zebra, hartebeest and topi.

During the period 1956–61 a number of blood meals were collected from *G. morsitans* caught in the Fort Jameson District and sent to Mr. (now Dr.) B. Weitz at the Lister Institute of Preventive Medicine where they were analysed in order to ascertain upon which hosts the sample had last fed. The results of this analysis are shown in Table 2. Many blood meals did not contain sufficient blood for any analysis and these have been omitted from the table. Others contained only sufficient for analysis to identify the host as belonging to one of four groups: primates, pigs, ruminants and unidentified mammals.

TABLE 2

HOSTS OF *G. morsitans* RECORDED IN FORT JAMESON DISTRICT

PIGS		
Warthog	17	
Bushpig	5	
Unidentified	6*	
TOTAL		28
RUMINANTS		
Buffalo	6	
Bushbuck	2	
Kudu	1	
Roan Antelope	1	
Duiker	1	
Unidentified	17*	
TOTAL		28
PRIMATES		
Man	7	
Unidentified	3	
TOTAL		10
OTHER MAMMALS		
Elephant	8	
Rhinoceros	1	
Hippopotamus	1	
TOTAL		10
UNIDENTIFIED MAMMALS		12
UNIDENTIFIED BIRD		1
TOTAL		89

*Includes one mixed feed pig ruminant

DISCUSSION

Table 2 shows that a total of twelve tsetse hosts (including an unknown bird) were recorded from the Fort Jameson District. The potential number of hosts are, of course, much greater, probably in the region of thirty five if the carnivores, larger reptiles and mammals such as porcupine and ant bear are included. The results are typical of those obtained in Tanganyika and Southern Rhodesia by Weitz & Glasgow in that the warthog is the most frequently fed upon host. Elephant appears to supply a larger proportion of feeds than in any of the areas sampled by Weitz & Glasgow, the highest they found being 8 per cent. in the Kariangwe–Sebungwe area of Southern Rhodesia.

Not all the Fort Jameson blood meals were collected from the area in which game elimination was taking place (on or at the edge of the plateau) and it is of interest to note the differences between those meals collected from the Luangwa Valley and those from the game elimination area. In the Luangwa Valley where host animals are comparatively abundant and presumably easy for the fly to find, meals were taken mainly from warthog and buffalo, whereas on or near the plateau where hosts are more scarce the fly was found to feed on a wider variety of hosts. This suggests that certain hosts (in this case warthog and buffalo) are definitely "preferred" but that where these become more difficult to find the fly will take feeds from whatever comes its way. The fact that the apparent host preference is altered by changing conditions in the environment was recorded many years ago by Lloyd *et al.* (1924) in Nigeria where they noted that in time of hunger *G. morsitans* tends to take a greater proportion of feeds from birds.

The reasons why the fly should tend to feed upon certain hosts and not others could be three in number:

(1) *Availability.* Hosts present in greater numbers might be expected to be fed upon more frequently, and in particular hosts which tend to spend more time in that part of the habitat forming the fly's feeding ground. Availability may be affected at that time of the year when grass cover is high and smaller hosts although plentiful may not be seen so readily.

(2) *Smell.* It may be that certain hosts give off a smell which is more attractive to the tsetse fly.

(3) *Appearance of the host.* It is fairly obvious that a larger host will be more easily seen than a smaller one and presumably will be detected by the tsetse fly at a greater distance. Also the colour of the host or intensity of reflected light from its surface may play an important part in attracting the fly.

It is tempting to believe that the latter reason plays a large part in determining the hosts on which *G. morsitans* will feed. Availability alone does not account for the pattern of feeds recorded in Fort Jameson, for in the Luangwa Valley where impala is the most abundant large mammal not a single feed was obtained from this species and on the plateau where duiker is the most common species only one feed was recorded from it. The hosts most frequently recorded were warthog, bushpig, buffalo, elephant and man, and assuming that feeds from the latter host were taken from indigenous man there is an evident tendency for feeds to be taken from the darker coloured hosts. It is well known that dark coloured surfaces on screens and traps are more effective in attracting and catching *G. morsitans*. There is further evidence that colour of the potential host may play a large part in determining whether or not *G. morsitans* is attracted to it, this being the case in zebra, which from Fort Jameson samples and those analysed by Weitz & Glasgow was not fed upon at all. Investigations carried out by Barras (1960) in Southern Rhodesia on the attractiveness of cloth screens to *G. morsitans* indicated that the least attractive surface to the fly is that which is painted with black and white stripes, although white adjacent to a black screen had no effect on the number of flies settling on it. Barras suggests that the breaking up of the black surfaces appears to be the critical factor in the fly's avoidance of a combination of black and white. The present author suggests that this may be the reason why zebra is apparently not included amongst the hosts of *G. morsitans*.

The information contained in this paper indicates that certain hosts are particularly "preferred" by *G. morsitans* in the Fort Jameson District but that in addition a much wider range of hosts are fed upon less frequently and this to a greater extent in areas where potential hosts are scarce and the hunger of the fly presumably greater. It is of interest to compare this with the numbers of the different species which have been destroyed as a result of the game elimination scheme.

The species destroyed in greatest numbers during the period 1956–61 were: warthog (691), duiker (383), kudu (343), bushpig (329), roan (270), buffalo (267), and eland (133). Of these warthog, bushpig and buffalo are among the most "preferred" hosts and their elimination appears to be thoroughly justified. The hunting of kudu is also probably justified for although this species was only once recorded in the list of Fort Jameson hosts, Weitz & Glasgow recorded 37 per cent. and 15 per cent. of feeds in two areas of Tanganyika as being taken from kudu. It appears likely that kudu might become a

"preferred" host in Fort Jameson should the numbers of, say, warthog, bushpig and buffalo become reduced. The case of roan antelope appears similar for although only once recorded as a host in Fort Jameson, Weitz & Glasgow recorded 25 per cent. and 14 per cent. roan feeds in two areas of Tanganyika. Eland has not been found to be a frequently fed upon host in Fort Jameson or elsewhere although this may be a result of its comparative scarcity in the areas concerned. Only one duiker feed was found and this follows the findings of Weitz & Glasgow who never recorded higher than 4 per cent. feeds from this species. In spite of its presence in comparatively large numbers it is low on the frequency table of tsetse hosts and it must be considered doubtful whether this species need be destroyed in a game elimination scheme. The same probably applies to other small species of which a few specimens were destroyed, namely oribi (6) and grysbok (3).

Elephant, although not particularly abundant in the areas where blood meals were collected (except in the Luangwa Valley where no feeds from it were recorded) appear to be one of the more "favoured" hosts and thus warrants inclusion in the list of species to be destroyed.

Reedbuck and bushbuck tend to be limited in their distribution and thus do not hold a high place on the list of hosts in Fort Jameson—only two feeds being recorded from bushbuck, and none from reedbuck. Weitz & Glasgow, however, found more frequent feeds from bushbuck in Southern Rhodesia and one area of Tanganyika (9 per cent. in each case) and from reedbuck in two areas of Tanganyika (25 per cent. and 10 per cent.). Their retention on the list of species to be destroyed might therefore be considered justifiable.

Zebra and hartebeest appear to be very rare hosts of *G. morsitans* if at all, and as mentioned above were removed from the list of species to be destroyed in 1959.

Impala and waterbuck only stray into the game elimination area at certain points and at infrequent intervals. Where impala was most abundant, in the Luangwa Valley, no feeds were recorded but in one area of Tanganyika, Weitz & Glasgow discovered 10 per cent. of feeds from this species. Mr. G. G. Robinson, the Provincial Entomologist at Livingstone, reports that a single feed from impala has been recorded in the Machili area. Although in the present investigation no feeds from waterbuck were discovered, 9 per cent. waterbuck feeds were found by Weitz & Glasgow in an area of the southern Sudan.

Sable antelope is one of the less common large mammals in Fort Jameson and as a result is unlikely to be a significant host although as a potential host it close resemblance to the roan antelope plus the fact of its darker colour suggest that it could be a "preferred" host if present in greater numbers. In Weitz & Glasgow's investigation feeds from sable could not be identified as such.

Rhinoceros also are comparatively rare and although only one feed was recorded in Fort Jameson, Weitz & Glasgow observed that wherever rhinoceros and *G. morsitans* inhabited the same area rhinoceros was always fed upon. Due to its low density on the ground it does not appear likely, on its own, to be capable of maintaining a tsetse population.

On the whole the game elimination scheme in Fort Jameson appears to have been realistic (with reservations given below) in so far as the majority of animals destroyed have been shown to be hosts of significance or at least of potential significance for *G. morsitans*. It appears justifiable to continue hunting buffalo, kudu, roan antelope, bushbuck, reedbuck, warthog, bushpig and elephant. The hunting of eland must be considered doubtful but additional evidence is required as to its status as a host of *G. morsitans* in the area under consideration. The hunting of duiker, oribi and grysbok must definitely be considered suspect for although duiker is the commonest larger mammal in the game elimination area it is lowly placed upon the list of hosts and it is possible that during the months when the grass cover is high the chances of the tsetse fly finding and feeding upon these species are poor. Impala and waterbuck, although they may be fed upon more frequently than analysis of blood meals collected in Fort Jameson suggests, are infrequent visitors to the area and might be left alone so long as this remains the case. It appears that hartebeest and zebra, for reasons given above, need not be hunted again unless evidence to the contrary is obtained. The hunting of rhinoceros and sable might be discontinued for a different reason. Although they may be potential hosts they are comparatively rare species and alone could hardly support a widespread tsetse population. On the grounds of conservation the hunting of these species might well be discontinued.

This paper suggests that game elimination as a means of tsetse control might be applied in a selective manner rather than as a wholesale slaughter of all the larger indigenous mammals in any area where control is considered necessary. However, it may be argued that there is little point in being selective in this process because the eventual aim of tsetse control operations must be to settle people upon the land cleared of fly and thus the game will in any event disappear from the area. True as this may be there are nevertheless two reasons why selective game elimination would be beneficial. Firstly, the hunters engaged on the actual hunting operations go through a laid-down procedure after shooting any animal which includes reporting the kill to their immediate senior officers. There are good reasons for this procedure being followed as it enables a thorough control to be kept on the whole game elimination scheme. This procedure, however, occupies time which might otherwise be spent in hunting. From 1960 onwards, Table 1 shows that more duiker were shot than any other species, this being a species which has apparently little, if any, significance as a tsetse host. At the time, hunting of duiker was thought to be a correct step, but since then no more than a single feed has been recorded from it. The time spent in their shooting plus that spent in going through the reporting and other procedures must have been considerable and might have been used to advantage in hunting species which are more frequent tsetse hosts. It is true to say that the animal which a hunter in the area under consideration is most likely to encounter and shoot at when out on patrol is the duiker, and as a result a high proportion of shots fired have done little to aid tsetse control and worse still have alerted all other animals within sound range. It appears therefore to be more advantageous that the hunters concentrate on hunting the more significant host species. Secondly there is the question of conservation of the rarer species to be considered. Although it may be rightly argued that these species will eventually disappear from the game elimination area when settlement follows, it seems more reasonable that they be gradually harried out of the area by the disturbance factors, caused by patrolling hunters, other tsetse control operations and eventual village or farm settlement, than that they be destroyed outright.

Two other considerations deserve mention. Firstly, if game elimination is considered to be necessary as a means of tsetse control in any particular area, then all efforts should be made to salvage scientific data from the animals destroyed. This was done in part of the area which has been the subject of this paper by Mr. V. J. Wilson, a Tsetse Control Supervisor stationed in the Fort Jameson District. That a wealth of information can be collected from a game elimination scheme has already been demonstrated in the Rhodesias by Riney & Child (1960) and Wilson & Clarke (1961). Lastly, special consideration should be given to the fact that the larger indigenous mammals of Africa are a source of protein supply which remains virtually untapped. There is little doubt that over most parts of Africa these animals can utilise the natural habitat far more efficiently than the domestic stock which is introduced by man. It is to be hoped that in future years particular emphasis will be laid by the Governments of African territories on studying the problem of conserving and cropping this supply as an alternative to the destruction of indigenous species only to replace them with the less efficient exotics which, furthermore, also probably help to bring about eventual deterioration of the habitat.

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Summary

1. The theory behind game elimination as a means of tsetse control is sound and its practical value has been proved in Southern Rhodesia.

2. In considering any game elimination scheme it is wise to ask whether sufficient numbers of animals are being eliminated and whether the right species are being shot.

3. A game elimination scheme in the Fort Jameson District has been in progress for many years and during the period 1956–1961 the most frequently shot species were warthog, bushpig, duiker, kudu, roan antelope, buffalo and eland. In addition a further eleven species were hunted.

4. During the same period, study of the local tsetse fly's host preferences by analysis of blood meals collected from the guts of tsetse flies indicated that warthog, elephant, man, buffalo and bushpig were "preferred" hosts.

5. These findings, together with those of earlier work on blood smear analyses, suggest that so far as the species hunted are concerned the Fort Jameson game elimination scheme has been generally realistic but hunting could become more selective to the advantage of the scheme itself and possible conservation interests.

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