INVASIVE RESEARCH, REDUCED LONGEVITY AND MORTALITY IN AN ENDANGERED SPECIES, THE AFRICAN WILD DOG *(Lycaon pictus)*,

with special reference to the extinction of the Serengeti-Mara study population 1985-91.

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'***The adverse effects of tagging may be subtle and important, although difficult to detect'*** (Tuyttens Macdonald & Raddam (2003)

' . the resolution of one question remains imperfectly ragged, despite exhaustive attention, and that is whether handling or vaccinating wild dogs had inadvertently contributed to their demise in the Serengeti-Mara ecosystem' (David Macdonald, Chair of the Canid Specialist Group, in Preface to: - IUCN, Species Survival Commission, Canid Specialist Group (CSG), Status Survey & Conservation Action Plan, 'The African Wild Dog' (Woodroffe et.al.1997)).

"*It is likely. that in many studies any adverse effects [of handling] are either unnoticed, perhaps because they are rare, or, more likely, because they are not reported"* (Laurenson 1992).

" from our results and PVA models presented previously (Burrows et al 1995 ,Ginsberg et al 1995b), it is difficult to determine whether the* extinction *of the Serengeti wild dog population is more likely to be due to chance alone (Ginsberg et al 1995b) or to invasive research methods (Burrows 1992)." (Cross and Beissinger 2001).

INTRODUCTION

The African Wild Dog *(Lycaon pictus)* an African endemic species is highly endangered with now perhaps less than 5,000 individuals. Between 1985-1991 the entire wild dog *study population* comprising 14 packs containing approximately 200 individuals died or disappeared from two study areas in the Serengeti-Mara ecosystem of Tanzania (Serengeti) and Kenya (Mara), East Africa where the species had been considered a 'flagship species' for conservation.

The ecosystem population did not become extinct in 1991 a non study population persisted within and around the ecosystem throughout the study period and persists to date.

All study packs were the subject of conservation research by scientists who routinely used invasive research techniques (known as ‘handling’); including immobilisation by anaesthetisation for radio-collaring and blood sampling of all new packs or groups located. Also in the Mara study population from 1987 onwards, sporadic experimental rabies vaccinations were carried out despite the lack of any serological *evidence at that time* that the packs in the Mara had been exposed to rabies virus. In 1990 a mass vaccination was carried out in the Serengeti study population which *had been naturally exposed to rabies virus pre vaccination*. Of the 13 Serengeti-Mara study packs known to have become extinct 77% *survived less than 4 months* after anaesthetisation and radio collaring of one or more individuals in the pack.

Rabies was confirmed in all cases where tissue samples suitable for analysis were obtained in both study areas and is the most probable cause of extinction of both unvaccinated and vaccinated study packs post 1985.

The claimed major aim of such invasive research is to facilitate the rapid detection of changes in wild dog demography, particularly *the extent and causes of mortality* and providing *early warning of major adverse changes in populations* over time. This it is claimed will enable wildlife managers to counter any identified short or long term problems particularly in endangered species. These claims remain unsubstantiated, as do claims that the benefits of invasive research outweigh the risks; the converse seems to apply.

The two Serengeti-Mara study populations one in 'Serengeti' (Tanzania) and the other approximately 175 km to the north in the ‘Mara’ (Kenya), together with a non study population in adjacent area formed part of a breeding population of at least 200 individuals with interchange between widely spaced packs via long range dispersal (often >100 km) of yearlings. Population Viability Analysis models suggest that large (>100) wild dog populations occupying large (>=5,000 km2) areas are unlikely to become extinct due to a chance event, such as a disease outbreak, and suggest that other factors were involved in the selective extirpation of the Serengeti (and Mara) study packs only *between 1985-91 whilst a non-study unhandled population persisted in adjacent areas.*

The anaesthetisation of wild dogs in captivity is known to be followed by a significant rapid increase in the levels of stress related corticosteroid hormones which are associated with immunosuppression. The efficacy of the inactivated rabies vaccines used, in producing an effective immune response in *Lycaon,* is unknown.

Analysis of the Serengeti data from 1985-August 1990 showed a statistically significant reduction in longevity of both handled individual wild dogs and their packs and suggested a causal relationship existed between handling and the rabies related extinction of the study packs within a few months of a handling event.

A 'handling-stress' hypothesis (also referred to as the 'handling-stress-immunosuppression' hypothesis) was proposed to explain this.(Burrows 1992, Burrows et.al. 1994 & 1995, Woodroffe 1997).

Analysis of data on handling in other study populations

The only data based investigation of the consequences of handling free living wild dog study packs in other *Lycaon* research studies is the much quoted analysis of Ginsberg et al (1995)

Most significantly Ginsberg et al claim that :- *' Our data show that there is no effect of handling on the longevity of Lycaon in any* [of 5] *ecosystem studied '*

This study provided some data from 5 study populations of wild dogs, including that in the Mara sector of the Serengeti-Mara ecosystem Ginsberg et. al. *did not investigate longevity* of individuals and their packs post handling which is the data used by Burrows et al', but estimated the *survival* of handled individuals during the 12 months post handling or in the case of unhandled dogs during the 12 months from first sighting of that individual . (Ginsberg et al 1995 Table 2).

This approach takes no account of the fact that unhandled 'yearling' and older subordinate wild dogs of both sexes often emigrate either as individuals or in the case of yearlings as single sex groups or that 'pack dissolution' will follow the death of either of the an alpha individual in a breeding pack.

Crucially Ginsberg et al.. incorrectly claimed that no individual in the study populations included in the study had been vaccinated by projectile dart.. In fact in 1990 one of the then only two study packs in the Masai Mara area of Kenya that provide data included in Ginsberg et al's analysis , had been completely rabies vaccinated by dart in late 1989 early 1990/ The other that was confirmed to have died from rabies 1991 contained was an older male dart rabies vaccinated when in the other fully vaccinated study pack (Nicholls Tail Tips 1 p.3 November 1990).

Recently, significant population declines have taken place in other handled wild dog study populations in Kruger National Park (South Africa) and Moremi Game Reserve (Botswana). Data from both these populations are included in the Ginsberg et. al, analysis .

Kruger N.P

In the period 1988-89 a total of 357 wild dogs in 26 packs were identified in Kruger National Park and some neighbouring reserves and the population was considered to have been stable over the last 25 years Maddock & Mills (1993)

From 1989 the Wild Dog population in Kruger National Park then became the most intensively continuously studied free living population in Africa until 2005 when such intensive studies ceased.. In July 2002 a long time Kruger Wild Dog researcher reported:-

***'The number of wild dogs here is down to under 200 now from over 400 a few years ago, and we really don't know why ' (G. Mills www.africanconservation.org).* Currently Kruger researchers suggest the decline was due to continuing years of above average rainfall.**

So until 2000 the Kruger population, the only viable free living population in South Africa, was considered to be stable, with no significant disease related adult mortality since pre 1990. However, in 2001 it became apparent that between 1995-2000, there had been a significant, but apparently unnoticed, decline of approximately 60% in number of individuals and a 30% reduction in the number of packs in this very intensively handled and managed population. There was no evidence of disease. Kruger scientists attribute this population crash to changes in rainfall in 1996-97 which they associate with reduced reproductive success of the packs.

However, just prior to the crash 2 adults *in each of the packs* (36 in 1995) were anaesthetised and blood sampled with the alpha pair in each pack, if known, being selected.

In Kruger, between 1990-93, 34 % of all radio collared individuals survived less than 12 months and researchers reported that 40 % of radio-collared and 53 % of radio-implanted and 21% of blood sampled only individuals wild dogs in study packs survived less than one year following 'handling' (Ginsberg et al 1995) . The Kruger data in Ginsberg et.al. refers only to individuals > 12 months old and so does not mention the fact that between 1989-94, 72 pups in the study packs were blood sampled for genetic research purposes. (Girman et al 1997)

No account of the likely stress involved to the ups or the other pack members particularly the alpha pair one or both of which, if known, were radio-collared. A decline in pup survival was noted during the invasive study period,

Northern Botswana

In this area including Moremi Game Reserve during the on-going research period (1989 to date) disease related adult mortality in wild dogs was unknown until 1996 when an unidentified disease, caused the extinction of 5 (38%) of the 5 study packs during a three week period. (McNutt quoted in Conniff 1999) No tissue samples were collected so the cause of death is unknown but considered to be a viral infection

In Moremi study, as in Kruger, one of the alpha pair in each study pack is usually selected for handling, for radio-collaring, with sometimes both alpha individuals being collared and blood samples taken . In Moremi 25% of radio-collared and 33% of blood sampled only individuals surviving less than on year following handling (Ginsberg et al 1995)

As radios expire within 19 months the Moremi dogs are re-anaesthetised to replace them. Unfortunately, despite the presence of radio-collared individuals in each study pack no tissue samples were obtained from the 5 Moremi packs lost in 1996. In Serengeti of the 5 handled packs which died in 1991, 4 containing radio-collared individuals but, as in Moremi, no tissue samples were taken.

No data are available on the longevity of the radio-collared alpha individuals in Moremi although it is known that 25% of all radio collared dogs in this study between 1989-93 died within 12 months of radio-collaring, but whether this was after the first collaring or re-collaring is not reported.

So in both Moremi and Kruger alpha dogs were alpha dogs were selected for blood sampling and/or radio-collaring rapid population declines took place coincident following invasive handling of study packs

The alpha pair are the main and usually the only breeding pair in a wild dog pack in any one year. Pack dissolution known to follow the loss of either of the alpha pair in a pack

In captivity South Africa and Namibia death from rabies of individuals vaccinated against rabies prior to release in re-introduced packs and groups emerged as a 'new' post 1988 phenomenon.

In Kruger the study population of *Lycaon* declined by approximately 60% from 434 in 1995 to 177 in 2000 . Intensive invasive research ended in 2005 with the population being just 120 individuals and reliance is now placed on photographic survey method only to estimate the population.

Exclusion of consideration of the 'Mara' data in Ginsberg et al (1995)

The Mara data in Ginsberg et al (1995) the only data in that much quoted paper directly comparable with the Serengeti data as the study packs had been rabies vaccinated was later excluded from consideration in the ongoing 'handling debate' as 'incomplete' (Woodroffe 1997).

However, despite the rejection of the Mara data , when reviewing the wild dog data from the Serengeti sector of the same ecosystem the same author concluded:-

"*The risks associated with immobilization and radiocollaring are questionable in Serengeti, and undetected elsewhere"* and *"The benefits of these interventions therefore appear to outweigh the costs at present."* (Woodroffe 2001 *Oryx*).

The data from the Kruger N.P and Northern Botswana reported by Ginsberg et al is also 'incomplete' and the claim that :- ' .. *no effect of handling on the longevity of Lycaon in any* [of 5] *ecosystem studied '* has no data basis.

The following comments are highly relevant to the ongoing on going 'handling effect' debate :-

"It is likely…. that in many studies any adverse effects [of handling] *are either unnoticed, perhaps because they are rare, or, more likely, because they are not reported"* (Laurenson 1992).

"Despite the potential impact that such activities [handling] *may have, it is frequently tacitly assumed ,or subjectively assessed, that these techniques have little effect on individuals in the long term"* (White & Garrot, 1990).

Wild Dogs 'return' to Serengeti following the ending of handling in post 1991

In the Serengeti and Mara handling of *Lycaon* officially ceased by 1992 and by 2000 it was reported that :-

'Since 2000,wild dogs have started to reappear across the entire region, from Loliondo region, across the Serengeti National Park and in NCA. The reason behind the reappearance of wild dogs is unknown,

one suggestion raised at the meeting was that the increased could be, at least in part, due to decreases in lion or hyaena numbers, however there are no data to support this conjecture.'
(Tanzania Wildlife Research Institute 2005 **)**
This workshop took place during a rabies epidemic in the ecosystem starting in late 2002 that did not affect wildlife within the protected area of SNP nor did it affect the increasing population of no - study packs and groups of *Lycaon* in the ecosystem that had not only survived post 1991 but expanded their population once invasive research was banned.

Unfortunately in 2007 invasive research began again and was followed in |October 2007 with the loss of a complete wild dog pack from disease with for the first time Canine Distemper confirmed in samples taken from *Lycaon* since research began in the mid 1960s (Goller et al 2010).

The pack that died close to the north **-**eastern boundary of the SNP was in the mass domestic dog vaccinations in the *'cordon sanitaire'* around SNP where local domestic dogs were routinely vaccinated against rabies, CDV and CPV. . It had been claimed that the cause of death of this pack had been due to poison. There is no data support for this widely publicised claim..

Wild dog pack extinction (other than by shooting) was not known in 'Serengeti' between 1965-85 i.e. before the introduction of routine intensive invasive research techniques involving *Lycaon* and trial mass vaccination of local domestic dogs that began in the 1990s

In contrast to the confirmed population declines in Kruger and Moremi, despite many published opinions expressed to the contrary, there is no evidence for a significant decline in the 'Serengeti' wild dog population (either in number of adults or number of resident packs) between 1965-78, or that the Serengeti plains study population was subject to a series of disease related population declines in any one year between 1965-85 i.e. *before* routine invasive research began (see Appendices 1&3).

Likewise there is no evidence that the significant increase, between the mid 1960s and 1986, in the number of spotted hyaena *commuting* to the Serengeti plains in the *wet seasons* when the dogs denned, had any significant effect on resident wild dog pack's nutrition, reproductive success or mortality. The hyaena increase had no observable effect, either pre 1985 when wild dog reproductive success was very low and immigrants very rare, or post 1985 when reproductive success was high, the population expanding and immigrants common. Due to frequent immigration of wild dogs to the Serengeti plains post 1979, the small study population was not, as is often claimed, genetically isolated.

Unfortunately any anecdotal hint of a decline in the Serengeti wild dog population *before* routine handling was introduced is considered by some commentators to be firm evidence of a series of catastrophic disease related population collapses in Serengeti (see Appendices 3a.-d.). By contrast, in Kruger where a 60% loss is *known* to have occurred *following an invasive research exercise*, this is claimed to be a natural population fluctuation to which wild dog packs are prone; and little comment has been made on the loss of the 5 study packs in Moremi.

Extinction of entire Wild dog packs from disease : A new phenomenon in 'Serengeti' post 1985

Prior to 1986 no pack extinction in the Serengeti was known other than those shot by rangers/game wardens as vermin, a practice which fortunately ceased in 1973. In 1986 the first *disease* related pack extinction (with pack behaviour suggesting rabies) in the ecosystem occurred within three months of the anaesthetisation and *radio-collaring,* of one subordinate adult dog, in one of the two Serengeti study packs.

The rate of disease related study pack extinction in Serengeti increased paralleling the increasing use of routine intensive invasive research techniques post 1985. Despite the extinction of Serengeti study packs in 1986, 1988, 1989 and 1990 (2) the Serengeti and Mara population was expanding with new packs replacing those lost (Appendix 8 and Table 3). This resulted from good reproductive success of the remaining study packs and the arrival of immigrant groups of both sexes.

Additional stressors to the study packs resulted from monthly or more frequent aerial monitoring between 1986-90 and the presence of tourist vehicles which followed hunting packs and the exposure to a variety of pathogens including a new virus, canid parvovirus. In September/October 1990 more than 80% of the study population in Serengeti was handled during mass vaccination against rabies, all had died with empty radio-collars being found from some individuals in the packs the rest simply disappeared by June 1991 (see Appendix 8 & Tables 4&5). An *unhandled* non study resident denning population persisted within and around the ecosystem throughout the period 1985-91 and persists to date. In both sectors of the ecosystem unhandled packs were still present after all study packs had died (Burrows et. al. 1995, Kat 1992).

The *pattern* of mortality in Serengeti changed significantly post vaccination. Between June 1986 - August 1990 (pre vaccination) 5 widely spaced study packs died, with rabies confirmed in one, all within 4 months of the *radio-collaring* of one or more individuals in the pack; other study and non study packs, some with home ranges overlapping that of the diseased pack, survived each study pack death. There was no evidence of inter-pack transmission of pathogens or of domestic dog vectors.

Post vaccination all *5 remaining study packs disappeared*, 2 packs died within 3 months of the *next anaesthetisation event in the pack* which involved the radio collaring of *a previously vaccinated individual.*

The effect of repeat handling of individual wild dogs is currently unknown (see Table 4).

After the Serengeti vaccinations, blood samples taken up to 2 years before vaccination, *were finally screened* and 46% were then found to be rabies seropositive. The population had been exposed to rabies in the environment pre vaccination and some survived. This suggests that some natural immunity existed pre but not post vaccination.

Prior to 1989, rabies had not been confirmed in any free-living population of wild dogs

In 1987 the first experimental vaccination of free living wildlife in Africa against rabies began in the Mara with the sporadic vaccinations of a few wild dogs in the only large study pack - the Aitong. In August 1989 older adults in the Aitong pack began to die within 2 months of the anaesthetisation and blood sampling of 8 individuals and the radio-collaring and rabies vaccination of 3 pups (10 months old).

The first free living pack in which some individuals had been vaccinated against rabies became the first free living pack in which rabies was confirmed.

Between December 1990 and January 1991 the other two Mara study packs died again with rabies confirmed in the only pack from which tissue samples were taken. One pack had been completely and the second partially vaccinated against rabies. (Appendix 8 & Table 4).

As all serum samples taken from Mara wild dogs prior to August 1989 (unlike those taken in the Serengeti) were claimed to be sero-negative for rabies. The rationale for the initial *sporadic* Mara vaccination of a few individuals in the Aitong pack in 1987 and subsequently, using inactivated vaccines developed for domestic dogs, in the absence of any confirmed threat of rabies is therefore unclear.

Similar strains of a locally common canid rabies virus were isolated from the Aitong Pack in the Mara and from an unvaccinated Serengeti wild dog study pack which in August 1990 died from rabies within *2 months* of the radio-collaring of two older adults one a subordinate female with pups.

In southern Africa there is no serological evidence of natural exposure of free living wild dogs to rabies. However, in Etosha NP, Namibia (1989 &1990) and Madikwe GR, South Africa (1997 & 2000) in packs in which some individuals had been vaccinated against rabies in captivity both vaccinated and unvaccinated individuals died from rabies after release. In 1993 rabies was for the first time confirmed in a free living *Lycaon* pack in Zimbabwe in the intensively handled population in Hwange N.P.

Rabies in wild dogs in southern Africa, where disease related mortality in wild dogs is rare, is a new phenomenon unreported prior to the introduction of intensive invasive handling including *vaccination*. There is no evidence that currently used rabies or canine distemper vaccines protect free living or captive wild dogs from challenge (East & Burrows 2001 and Appendix 1&8 and Tables 4-5).

The 'Handling-Stress Hypothesis'

An hypothesis that that small populations of endangered species may be driven to extinction by the very researchers whose concern it is to keep the animals alive was proposed based on data collected by various researchers from a study population of *Lycaon* in Serengeti from 1965-1991. Based on analysis of these data (Burrows 1992, Burrows et al 1994 & 1995) it was concluded that the most likely explanation for the demise of the study packs by mid 1991 is that intervention-induced stress following the introduction in 1985 of routine invasive research involving field techniques such as trapping, darting ,tagging, radio-collaring, tissue sampling collectively known as 'handling', should not be ignored as factors influencing the fate of species under threat.

Between 1985 and August 1990 sporadic pack deaths occurred with rabies confirmed or suspected within a few months of a handling events for radio-collaring and blood sampling mainly of individual older dogs. Most of the individuals in these packs were 'unhandled'. In 1991 however, within a few months of the mass vaccination (of more than 80% of the study pack individuals) against rabies all the study packs died with rabies confirmed in two packs in the Mara sector of the ecosystem. (Burrows et. al. 1995, Kat 1992).

The Serengeti data from 1985-August 1990 suggested that a direct causal relationship existed between 'handling' and reduced individual and pack longevity. The stress hypothesis also later referred to as the 'handling-stress', or the 'handling stress-immunosuppression' hypothesis was proposed to explain this. (Burrows 1992).

The hypothesis is based on the basic premise *that all forms of handling of wild dog is stressful* to the individual(s) and their pack and results in the elevation of stress related corticosteroid hormone levels.

The data suggest that anaesthetisation and radio-collaring of and older (mainly post 'dispersers' i.e. those that have left their natal pack) subordinate adult individuals has the greatest adverse effect on individual and their pack's longevity with little evidence of such effects when yearlings in their natal packs are handled for radio-collaring and blood sampling.

The hypothesis attempts to explain the phenomenon of pack extinction from disease with rabies suspected in 1986-88 and confirmed in 1990 and the post rabies related extinction of the entire *Lycaon* study population in the ecosystem following the mass vaccination of the study packs in 1989 1990 when there was no evidence of a rabies epidemic/epizootic in domestic dogs in adjacent areas or other species of wildlife and a non study unvaccinated *Lycaon* population survived with no evidence of a general rabies epidemic.

The existence of asymptomatic rabies 'carrier' domestic dogs has been confirmed in Nigeria and Ethiopia. Recently Serengeti Spotted hyaena have been found to be 'carriers' of a different rabies strain from the one isolated from the Serengeti and Mara *Lycaon*, but with no associated mortality. Both Bat-eared fox and White-tailed mongoose in Serengeti are known to suffer periodic *limited mortality* from rabies (Maas 1993, Burrows 1995).

The 'handling-stress' hypothesis therefore could explain the phenomenon of sporadic disease related pack extinction from between 1985-90 and why there was a sudden devastating change in disease related study pack extinction in the Serengeti in 19900 1991:coincident with the mass handling for rabies vaccinations mainly by dart of most individuals in the study packs in both sectors of the ecosystem -

Why did rabies emerge post 1985 as a new problem in 'handled' wild dog packs?

To explain why free living packs, some known to have been *naturally exposed to rabies virus* and with some sero-positive individuals, should die from rabies post handling, a possible *mechanism was suggested*:

If an asymptomatic wild dog 'carrier' of rabies in which the virus is 'latent' is handled, the stress induced rapid rise in corticosteroid hormone levels may result in immunosuppression allowing activation of the virus leading to clinical rabies and pack death. The anaesthetisation by dart of wild dogs in captivity in South Africa is known to be followed by a significant rapid increase in the stress related corticosteroid hormones associated with immunosuppression.

The handling-stress hypothesis can explain the sporadic loss of 5 Serengeti radio-collared packs pre vaccination, the sudden extinction of the remaining 5 Serengeti study packs in 1991 following the mass vaccinations of August /September 1990, and also the loss of the 3 Mara study packs from rabies between 1989 and 1990. Pre vaccination i.e. pre September 1990, the chance of targeting a 'carrier' in a pack when a single dog was selected for radio-collaring was much less than that when most individuals in the packs were handled for vaccination in 1990.

An alternative *mechanism,* also consistent with the basic premise of the hypothesis, is that handling stress induced immunosuppression, particularly following the Serengeti mass vaccination against rabies of packs *already naturally exposed to rabies virus*, may lead to greater susceptibility of some stress-immunosuppressed individuals to rabies virus (or any other pathogen) in the environment when the pathogen is next encountered. This again leading to clinical rabies and transmission to the rest of the pack. This alternative *mechanism* could explain not only the outbreaks of rabies post vaccination in Serengeti- Mara but also cases reported in captive wild dog vaccinated against rabies before release into reserves in Namibia and South Africa.

The possibility that some seropositive wild dog or other wildlife species may act as asymptomatic potentially infectious 'carriers' of rabies and possibly the source of outbreaks in *Lycaon* has not been investigated.

IUCN Canid Specialist Group (CSG) response to pack extinction and the handling-stress hypothesis

Initially the extinction of all 5 Serengeti study packs from rabies in 1991 was questioned by IUCN Canid Specialist Group (CSG) claiming that despite the retrieval of empty radio collars and some skeletal material the disappearance of all study packs did not prove high mortality, and that failure to locate the packs was probably due to lack of monitoring and some emigration. Rabies had been confirmed in all three study packs in the ecosystem from which suitable tissue samples were obtained, including those in 1989 and 1990 from vaccinated individuals in the Mara. Despite this in 1992 CSG claimed that as the Serengeti study packs had been vaccinated against rabies they probably did not die from rabies. It was suggested that some other pathogen such as Canine Distemper may be involved, despite there being no serological evidence of exposure of any wild dogs in the ecosystem to this pathogen.

[The claim made in a recent book that in 1990 the Tanzanian and Kenya study packs were decimated by rabies is correct (McNutt & Boggs 1996). The claim by the same authors that in 1991 when the rest of the study population died out that, *" ..evidence indicated that a canine distemper virus, originating from the domestic dog population in the area, was responsible for the second and final epidemic"*. is incorrect, there is no such evidence.

However, in 1992 CSG proposed an immediate moratorium on handling of wild dog in Serengeti and initiated an analysis of data (to be carried out by Dr. J.Ginsberg) from other handled study populations, including the Mara. Data from the Mara was crucial as this was the only other open plains dwelling *Lycaon* population, all the remaining study populations in Africa being in woodlands. The Mara was also the only other study population with high disease related mortality and, crucially, in which free living packs had been exposed to, vaccinated against and died from rabies (East 1996).

Unfortunately any possible adverse effects of the first experimental vaccination of free living wild dogs in Africa, which began in the Mara in 1987, were not considered by CSG in their data analysis (Ginsberg et al 1995a.). Dart vaccination was not considered a form of 'handling' and individuals so treated, at least 16 individuals including all 9 in one of the three study packs (cf. just 2 in one pack as stated by Ginsberg 1996), were included in CSG's analysis in the 'unhandled' category.

The results of the data analysis were circulated in August 1993. At that date, and up to 1999, CSG reported the existence of an *unhandled* population in the ecosystem. CSG recommended that only half of the packs, which 'migrate' back into the Serengeti, should be handled, in order to permit a comparison between handled and non handled packs. Packs do not *migrate*, single sex groups and individuals *emigrate* from existing packs.

The claim that *"… the data presented by Burrows (Burrows et al 1994, Burrows 1995) show clearly that the decline in the Serengeti Lycaon population began in the early 1970s, nearly two decades before intensive handling began "*. (Ginsberg et al 1995b, p. 673) is misleading (see Appendix 3a.-d. & 4.).

The implied significant decline (1970-73) and pack losses was based on incorrect data for 1970 and the actual decline post 1970 was not statistically significant. It was due to a reduction in the mean numbers of individuals in the study packs due to poor reproductive success and lack of immigrants and not due to a fall in the number of packs. There was no sudden pack extinction, other than from shooting, until 1986 (Burrows 1995).

The *loss of whole packs from disease was a post 1985 phenomenon coincident with the introduction of intensive invasive handling* of the packs in both sectors of the ecosystem (see Appendices 1,2 & 3 and Tables 3,4 & 5). As a number of authors, including Ginsberg, have pointed out, the pack rather than the individual must be considered the basic unit of the population (e.g. Woodroffe & Ginsberg 1999).

When in 1997 the death of all the study population was finally acknowledged by CSG it was accepted that rabies was probably the cause of study pack losses in all cases. CSG also accepted that a statistically significant association between handling and reduced *longevity* of both individuals and packs had been demonstrated in the Serengeti data, but in their reviewer/spokesperson's (Dr.R.Woodroffe) opinion it is not necessary to invoke a causal relationship.

It is claimed that the Serengeti data can be explained as due to a chance *post vaccination* epidemic/disease outbreak from which rabies vaccinations failed to protect some packs (Woodroffe 1997). The chair of CSG is not so certain (see quotation at top of page 1).

CSG's alternative 'disease outbreak' hypothesis cannot explain sporadic study pack extinctions 1986-90 and persistence of an unhandled non study population pre and post 1991

This hypothesis claims that the Serengeti data can be simply explained not only by a hypothetical disease outbreak

but by its timing which, based on the claim that vaccinated dogs had less time to live before the epidemic than unvaccinated dogs (Woodroffe 1997), the putative epidemic must have been *post vaccination*. The first Serengeti pack to disappear *post vaccination* (the Ndoha) was last seen alive in January 1991 (Woodroffe 1997 Table A1.1) so any post vaccination 'epidemic' in Serengeti must have begun in 1991 *not vaguely* in 1990-91 as Woodroffe claims.
Further :- *" ..it seems unlikely that a highly pathogenic strain of rabies was responsible for the disappearance of wild dogs from the Serengeti -Mara "* (Woodroffe 1997).

An epidemic of rabies of a non highly pathogenic strain in 1991 cannot explain the sporadic deaths of 5 unvaccinated Serengeti study packs between 1986-August 1990 one with rabies confirmed and suspected in the others, which was the very basis for the stress/rabies hypothesis, nor can it explain the extinction between 1989 and late 1990 of all the Mara study packs, again with rabies confirmed.

Why should a non highly pathogenic strain of rabies virus cause limited sporadic death of 5 Serengeti wild dog packs within a few months of a radio-collaring event in each pack pre vaccination but suddenly in 1991, post vaccination against rabies with an inactivated vaccine, lead to the elimination of all study packs?

The evidence suggests that the same common 'canid' strain of rabies virus identified in Serengeti in the rabid pack of 1990 (pre vaccination) was most likely also the cause of the sporadic study pack deaths in Serengeti from 1986-90 and also caused the deaths of the 3 packs in the Mara between 1989-90 and the 5 pack deaths in Serengeti in 1991 post vaccination.

No evidence for a general rabies epidemic in the ecosystem in 1991

Rabies virus of at least two strains (one a common canid strain and the other unique to hyaena) is known to be *endemic* in some Serengeti wildlife but there is no evidence of *epidemic* rabies in wildlife or domestic dogs in, or around, the ecosystem post 1977. Despite the loss of all study packs by mid 1991 a non-study population of wild dogs persisted and persists to date. There is no evidence for a general rabies epidemic in 1991 which would have been expected not only to affect wild dogs but other susceptible wildlife and local domestic dogs in and around Serengeti. No such mortality was reported by researchers, rangers or the many tourist which closely observe this area throughout the year.

An unhandled non study Wild dog population existed pre 1991 and persists to date

In 1999, mindful of the problem presented by a putative ‘epidemic’ that apparently selectively afflicted only handled wild dog study packs, the impact of CSG’s hypothetical 1991 'disease outbreak' was suddenly expanded to a claim that the entire ecosystem wild dog population and with it a unique genotype became extinct (Woodroffe & Ginsberg 1999).

It had earlier been claimed that the many confirmed wild dog sightings in the ecosystem post 1991 were all 'immigrants'. This is neither consistent with the claim that the Serengeti population was isolated, nor CSG's distribution maps in their 1997 Action Plan which show wild dogs as 'vagrants' or absent in the areas adjacent to the former study areas in Tanzania and Kenya. (Woodroffe et.al. 1997).

The claimed extinction of the entire Serengeti-Mara ecosystem wild dog population in 1991 is a myth: an unhandled resident breeding population existed *in the ecosystem* pre 1991 and persists to date (2006).

Woodroffe’s alternative 1991 ‘disease outbreak’ hypothesis and claimed extinction of the entire Serengeti -Mara ecosystem wild dog population can be dismissed as it neither explains the pattern of Serengeti study pack extinction *beginning in 1986*, nor can it explain the Mara data or why a non study population survived.

Population Viability Analysis models

Doubts were recently expressed concerning the ability of Population Viability Analysis models to help elucidate the cause of the loss of the Serengeti packs:-

"…. from our results and PVA models presented previously (Burrows et al 1995 ,Ginsberg et al 1995b), it is difficult to determine whether the extinction of the Serengeti wild dog population is more likely to be due to chance alone (Ginsberg et al 1995b) or to invasive research methods (Burrows 1992)." Cross and Beissinger (2001).

The Ginsberg et al's use of demographic data for 1975-76 on which their PVA model is largely based is fatally flawed (see Appendix 3d.). Unfortunately, Cross and Beissinger would not have been aware of this when drawing their important conclusion.

CSG accept a statistically significant association between handling and reduced longevity

in Serengeti data but claim that handling is not causally associated with mortality and reduced longevity in any ecosystem.

This claim is based on a flawed 'survival' analysis of data from originally 5 (Ginsberg et al 1995a) now reduced to 4 other 'ecosystems' with the Mara data now excluded (East 1996, Woodroffe et al 1997) and a Population Viability Assessment model (Ginsberg et al 1995b) using incorrect data (see Appendix 3d.).

The validity of the Mara data in CSG's 'survival' analysis was questioned, following which an attempt, that unfortunately failed, was made to obtain the full Mara data from the researchers concerned, particularly those data relating to the actual numbers of individuals vaccinated (Woodroffe 1997). Therefore in 1997 the Mara data supplied to CSG in 1993, *the only data of relevance to those from the Serengeti, was discounted as 'incomplete'.* Yet it was mainly on the basis of this 'incomplete' and inaccurate data from the Mara (Burrows et al 1995), the northern sector of the same ecosystem in Ginsberg's analysis that, in 1993, CSG recommended the lifting of the moratorium on handling in Serengeti. If as Woodroffe & Ginsberg (1998) claim the entire ecosystem *Lycaon* population had become extinct there would have been little point in lifted the moratorium on handling.

The claim that handling had no effect on the survival of handled wild dogs in any of the five ecosystems studied between 1987-93 (Ginsberg et al 1995a) has now been reduced to four: Kruger NP (South Africa), Moremi GR (Botswana), Selous GR (Tanzania) and Hwange NP (Zimbabwe). All are in woodland habitats where, up to 1996, the populations were considered stable, or increasing, and disease related adult mortality was rare with no evidence of exposure to rabies. Data from such populations was therefore largely irrelevant as a *test* of the handling-stress hypothesis which related specifically to a wild dog population in Serengeti known to be exposed to, vaccinated against and died from rabies (East 1996).

Is there evidence for handling-stress related problems in other wild dog study populations?

Although the handling-stress hypothesis was originally based on Serengeti data, other published data suggests handling problems in other populations, whatever the precise *mechanism* involved may be. Handling-stress may explain population declines and rabies deaths in other wild dog study populations. For example data from the Mara study area in Kenya (1987-90) show that 33% radio-collared dogs and 70% of those blood sampled survived less than 12 months following anaesthetisation. In South Africa and Namibia unexpected outbreaks of rabies *in vaccinated* translocated or reintroduced packs and groups emerged as a 'new' post 1988 phenomenon. In Kruger (1990--93) 53% of individuals implanted with radio-transmitters and 40% of those fitted with radio-collars survived less than 12 months post handling (Ginsberg et.al. 1995a: also see this Appendix 7).

The comparative data for survival of *unhandled* individuals in the Ginsberg et.al. study is based on the false assumption that dispersal equals death. The confirmed high survival of dispersing unhandled individuals (and, in Serengeti, radio collared yearlings) post emigration is ignored (Burrows 1995, Burrows et.al. 1995).

More recently in Kruger NP, prior to a dramatic decline in reproductive success in 1996 and 1997, *the alpha pair if known, or if not another adult pair in each pack (36 packs in 1995)*, were anaesthetised and blood sampled (Girman et al 2001). Similarly in Moremi at least one of the alpha pair was usually selected for anaesthetisation this time for radio-collaring and blood sampling (McNutt 1996). Any adverse effect on subsequent reproductive success, or on disease related or accidental death, following the deliberate selection of breeding individuals for anaesthetisation to provide data for such research projects was not, it appears, considered to be important. *The death of either of the alpha pair will result in pack dissolution (*Burrows: <www.africanconservation.org>)

These worrying developments suggest that a causal association between handling and rabies in wild dog packs exists in other ecosystems but is being ignored . A population decline in Kruger following the anaesthetisation of so many adult dogs in the National Park would be predicted from the handling-stress hypothesis whatever the precise causal *mechanism* involved.

Uncritical use of raw and inappropriate data.

Most reviewers of the Serengeti wild dog demographic data for the 1960s and 1970s uncritically accept raw data showing inter-year fluctuations in the *number of known and unknown individuals* seen in a study area in a year by different observers as an accurate reflection of the health of *the population.*

The Serengeti plains packs studied from 1964 onwards was NOT the entire population of 'Serengeti', the National Park the 'ecological unit' or the ecosystem as is implied by some commentators (e.g. Estes 1991, Creel 1992) it was geographically and logistically a convenient sample to study.

Anecdotal accounts and opinions expressed in popular books and some research publications of *claimed* disease related population crashes in Serengeti wild dog study packs between 1967-77 have been uncritically accepted as facts. Such 'facts' are the basis of a claimed 1971-3 population crash, continued decline and further crash in 1975-6 which would, due to chance events alone, such as an 'epidemic', lead to the inevitable extinction of the small Serengeti ecosystem population of wild dogs (e.g. Estes 1991, Ginsberg et al 1995b, Ginsberg 1996, Creel 1992).

Therefore, it is conveniently concluded, that there is no need to look for any other cause. Any possible adverse effects of handling can therefore be ignored and routine handling for data collection continue unhindered. However, this convenient self-fulfilling prophecy is contradicted by all the available evidence (Burrows 1994, Anon 1994; and see this Appendix 8 and Tables 2&3).

Based on *published data* the same number of packs (5) were present on the Serengeti plains *in early 1991 as in 1970* (Burrows 1993, and see Appendix 4 & Table 1. There is no evidence for either a series of population crashes or a dramatic decline in the Serengeti population of wild dogs before the introduction of routine invasive handling i.e. pre 1985

Prior to 1991 there is no evidence for a significant change in the number of wild dog *packs* resident on the Serengeti plains from 1964-91 (Burrows et al 1994, & this Table 1).

The decline in the Serengeti wild dog study population in the 1970s was in the *mean number of adults* in the study packs *not in the number of packs* the basic unit of the wild dog population (Woodroffe & Ginsberg 1999) and was caused by a prolonged (8 year), but temporary significant decline in reproductive success *and* a lack of immigrants (Appendix 4.).
The lack of immigrants suggests that whatever the cause of poor reproductive success it affected wild dog packs not only in Serengeti but over a very wide area (see Appendix 7 for a possible explanation). Post 1978 the wild dog population in both Serengeti and the Mara *was expanding up to 1990*, despite the sporadic extinction of whole study packs, due to good reproductive success of the remaining packs and immigration of unknown groups (Fuller et al 1992, Burrows 1995).

By contrast in Kruger *just 2 years of poor reproductive success* and pup survival is claimed to have resulted in a significant decline in numbers of individuals which might be expected. What this would not explain is the dramatic fall in the *number of packs* which would not be expected. The loss of reproductive success *alone* cannot explain the Kruger data from 1995-2000, which suggests that this population decline, *unlike that in Serengeti in the 1970s*, involved high adult mortality.

No data analysis of the effects of the extensive handling post 1993 has been published

To date, since their limited *survival* analyses based on data collected up to and including 1993 (Ginsberg et. al. 1995a), *no further data* from any of the ecosystems where handling of wild dog continued with greatly increasing frequency for up to a further nine years post 1993, has been published to support CSG's contention that handling has no effect on longevity or survival in any of the ecosystems, or is essential for the conservation of wild dogs.

Currently there are no unhandled *study packs* in Africa from which base line data on individual and pack longevity is being collected by non invasive techniques. The only such data comes from Serengeti where both the *longevity* of unhandled individuals and their packs was significantly greater than that following the introduction of routine invasive handling in that ecosystem in 1985 (Burrows et al 1994).

In the opinion of Woodroffe, the sole author of CSG Action Plan Appendix 1, the association, post 1985, between intensive handling and reduced longevity in the Serengeti data set can be explained by a hypothetical disease outbreak/epidemic without assuming a causal relationship (Woodroffe 1997). There is no evidence for such an epidemic at such a time. The chair of CSG is obviously equally unsure (see page 1).

However, on the basis of a flawed PVA model, an irrelevant and a flawed 'survival' analysis (Ginsberg et.al. a&b) and the timing of a hypothetical epidemic for which there is no evidence (Woodroffe 1997), Woodroffe claims to be able to reject the handling-stress hypothesis as " *not the best explanation"* for the loss of the Serengeti -Mara study packs between 1995-91 (Woodroffe 1997).

It may not be the 'best' but it is currently the only explanation that fits the data for the reduced longevity of handled individuals and their packs post 1985 and the associated pattern of mortality pre and post vaccination in Serengeti and Mara wild dogs whatever the precise *mechanism* involved may be (Burrows et al 1995 & 1995).

The claimed benefits of invasive research lack supporting data

"Despite the potential impact that such activities [handling] *may have, it is frequently tacitly assumed ,or subjectively assessed, that these techniques have little effect on individuals in the long term"* (White & Garrot, 1990).

"The tacit assumption that immunisation can only benefit a population is a dangerous one, particularly when dealing with free-living animals."(Hall & Harwood 1990).

"It is likely…. that in many studies any adverse effects [of handling] *are either unnoticed, perhaps because they are rare, or, more likely, because they are not reported"* (Laurenson 1992)

The current routine use of radio collaring in wild dog research is based on an assumption that any inevitable risks involved are outweighed by the benefits and a claim that it is essential in facilitating data collection.

Unfortunately the plethora of research papers on wild dogs post 1990, most based on use of data collected using invasive techniques, have failed to provide information of any practical help to wildlife managers such as early warning of disease problems or major fluctuations in population and their causes. Apart from Serengeti, nothing is published from other studies relating to the *longevity* of radio-collared individuals compared with that of unhandled members of the same population, or the cause of death of so many radio collared individuals, most vaguely attributed to 'natural causes' (Ginsberg et al 1995a see Appendix 5).

Is routine invasive handling of free living wild dog essential for the welfare and conservation of the species?

To date invasive research on wild dogs has failed to provide any clear welfare or conservation benefits to any population of this highly endangered species (Appendix 1&5 and Tables 3-5).

Analysis of data from wild dogs obtained by invasive research showing that such techniques enhance, rather than decrease, the survival of free living or translocated populations has yet to be produced. Analysis of Serengeti and Mara data suggest adverse effects of handling. This begs the question: why continue to use such techniques when non invasive techniques are available? (Appendix 2.).

"*To minimize risks, however, wild dogs should only be immobilized or radio collared when …. there is a clear conservation benefit to the study …."* (Woodroffe 2001).

Unfortunately to date, the 'risks' involved *in any ecosystem* where such risks need to be minimized have not been assessed. Woodroffe's conclusions concerning the risks associated with immobilization/anaesthetisation and radio-collaring are based on the 'incomplete' and very limited analysis of data from 4 ecosystems up to 1993 on *survival* of individuals up to 12 months post handling for radio-collaring and blood sampling only (Ginsberg et al 1995a) and a statistically flawed analysis (Creel et al 1997) of the effect of radio collaring on stress hormones mainly in males *selected* for their vigour (East et al 1997).

Until the risks involved in all forms of handling are properly assessed, *taking into account the published data on handling collected from packs throughout Africa pre 1994 and from those that have continued to be intensively handled since 1993 which remain unpublished;* any benefits of handling to welfare and conservation of wild dogs in the wild, or in translocated packs remain to be demonstrated.

It is essential that all handling data including details of age, sex and social position of the individuals handled and the historic vaccination data from the Mara should be made available.

The costs in terms of death of wild dog packs and groups following all vaccinations and within less than 4 months of radio collaring in Serengeti-Mara and unexplained population declines in Kruger and Moremi following anaesthetisation of alpha individuals appear to be very high.

The Serengeti analysis, associating handling with reduced longevity of individuals and pack is recognised (Anon 1994, Woodroffe 1997). It now appears that handling induced stress may also contribute to other population declines and the loss of handled free living and managed reintroduced wild dog study populations from rabies in southern Africa, *whatever the mechanism involved may be.*

The ability of some researchers to ignore the obvious risks involved in anaesthetising any animal and their dismissal of any suggestion that handling may be detrimental to wild dog individuals and their packs is clearly displayed in a recent publication:-

In Kruger National Park which has the only viable wild dog population in South Africa :-

"*To test* ..[an]…*hypothesis, the alpha male and female if known (Girman et al 1997), or one adult male and one female from each pack in the Kruger population were selected"* . (Girman et al 2001).

The selected individuals were anaesthetised and blood sampled just prior to the dramatic 60% population crash of 1995-2000.

The Kruger research clearly seems to conflict with recent statements made by IUCN CSG spokesperson on wild dogs:-

"It is vital that future plans for wild dog conservation be based upon realistic assessments of the costs and benefits of intervention. "

and :- "*To minimize risks, however, wild dogs should only be immobilized or radio collared when …. there is a clear conservation benefit to the study …."* (Woodroffe 2001).

Given the known risks of immobilising/anaesthetising individuals, the practise of radio collaring and re-collaring previously collared alpha individuals as in Moremi GR would appear to be particularly dangerous and is perhaps one of the reasons for the reported low pack longevity in Moremi with most packs not lasting more than 2 years (McNutt 2000) and the catastrophic decline in the Kruger population between 1995-2000.

Despite the accepted statistically significant association between handling and reduced longevity in the Serengeti study population and the confirmation of rabies as the only known cause of study pack deaths in the Serengeti and the Mara and the comments of the IUCN CSG (see above and page 1) an extraordinary claim and recommendation is made :-

"Causes of mortality in the wild dog population are still unknown. To rescue this endangered species an intensive radiotelemetry study is required" (Sinclair 1995).

If, as is claimed, the entire Serengeti-Mara population became extinct in 1991 (Woodroffe & Ginsberg 1999) Sinclair's recommendation would be the equivalent to attempting to rescue the Dodo. It is also extremely ill advised given the uncertainty of the extent to which handling precipitated the extinction of the Serengeti-Mara study packs in 1991 and the association of all forms of handling both free living and captive populations of *Lycaon* with high mortality (Burrows et.al. 1994 & 1995, Anon 1994, East 1996, East et.al. 1997, Woodroffe 1997, East & Burrows 2001, van de Bildt 2002).

However, as the entire Serengeti-Mara population did not become extinct in 1991, then by ignoring all the available scientific data, Sinclair's recommendation for an intensive radio telemetry study is more likely to hasten the decline of this endangered species than to rescue it.

A former warden in Serengeti from 1956-72 wrote:- *"One thing is sure : it* [research] *was a great confidence trick, and virtually nothing has ever come out of it to help the hard-pressed animals of East Africa* (Turner 1987,163).

CONCLUSIONS AND RECOMMENDATIONS

Based on the Serengeti and Mara data derived from study packs all of which were radio-collared it can be concluded that:-

1. The risks involved in the Serengeti of immobilization/anaesthetisation of individuals exposed to rabies and in particular of older adults not in their natal pack's home range appear to be very high with death of the individual and their pack from rabies all within 4 months (n=6, average 2.5 months).
2. The survival of individuals *of any age* (and their packs) which have been/are exposed to rabies virus, dart vaccinated and subsequently radio collared, i.e. handled at least twice, is low (n =2, average 2 months). The majority (70%) of dart vaccinated individuals which died were in these 2 packs (Salei & Ndoha) which were handled in this way in early 1991. This accounts for the fact that dart-vaccinated individuals which were not immobilized had the shortest mean survival after handling.

3 The average survival post immobilization/anaesthetisation of *unvaccinated* yearling pre dispersers is 25 months cf. 2.5 months for older individuals handled as post-dispersers (1. above).

4. The vaccination of free living wild dogs and those in captivity prior to release with inactivated vaccines developed for domestic dogs is associated with high mortality from rabies.

5. The death of either of the alpha pair in Serengeti and other ecosystems is usually followed by dissolution of the pack with the pack splitting into single sex groups.

6. Genetic and other studies can now be undertaken using non invasive methods.

7. The claim that routine invasive research is 'safe', with any risks outweighing the inevitable risks involved, and is essential for the conservation of *Lycaon* has no data support from any ecosystem .

From the conclusions above practical recommendations follow:-

1. If for *very good conservation reasons* it is considered essential to radio-collar a free living wild dog, it should be a yearling still in its natal pack's home range.

2. Due to the inevitability of pack dissolution or other disruption following the accidental death of an alpha dog in a pack, no individual of alpha status should be immobilised/anaesthetised or 'bounce dart' tissue sampled.

3. It is crucial that the role of cell mediated immunity in protecting wild dogs from naturally occurring pathogens in their environment be understood. Currently the effect of stress on cell mediated immunity in *Lycaon* is unknown. The available vaccination data (from both free living and captive groups) strongly suggests that, the immune system, particularly of older *Lycaon* individuals is unusual.

4. Free living wild dog packs and individuals should not be subjected to experimental invasive research.

5. The remaining viable and self sustaining populations such as those in Ruaha National Park and Selous Game Reserve / Mikumi National Park in Tanzania should be invasive research free areas and, by concentrating on the conservation of habitat and education, conserve all their diverse inhabitants including their vitally important populations of wild dogs.

6. If research on this endangered species is to achieve its claimed aims of improving the welfare and survival of free living and captive wild dogs all relevant data and the sometimes contentious and inconvenient conclusions drawn from them must be fully published and taken into account.

7. Mass vaccinations of domestic dogs that were coincident with CD epidemics in rabies vaccinated domestic dogs in the Mara in 1991 and in Serengeti-Mara 1992-3 and the rabies epidemic of 2002-2006 that began in domestic dogs mass vaccinated around SNP from 1996 onwards.

8. The claim that local domestic dogs around the wildlife conservation areas in Serengeti-Mara ecosystem are the only reservoir of infection for canid diseases for wildlife in SNP , and in particularly rabies, has no data support. And
9 Possible wildlife reservoirs of rabies need to be investigated before further mass triple vaccinations of often disease and ill- nourished semi-feral local breeds of domestic dogs are carried out.

Based on data already collected and available these recommendations, if adopted, are likely to have very positive effects on the future welfare and conservation of the remaining free-living wild dogs and other wildlife species in Africa.

A recent 'Letter to Nature ' (Saraux et al., 13 January 2011) presented data showing the long term adverse effects of the systematic use by researchers of 'flipper - banding ' in free living King penguins *(Aptenodytes patagonicus).*

The authors state:- ***'We show that only long-term investigations may allow an evaluation of the impact of flipper bands and that every major life -history trait can be affected, calling into question the banding schemes still going on. In addition ,our understanding of the effects of climate change on marine ecosystems based on flipper -band data should be reconsidered.'***

A recent paper relating to research on the *Lycaon* population in northern Kenya (Woodroffe 2011 (Journal of Mammalogy 92 (2):305-315) reports that *Lycaon* and man and his doemstic animals including dogs can successfully co-exist . Woodroffe reports that :-

' --- no demographic Allee effect was detectable. These results show that, despite earlier concerns, wild dogs can achieve rapid population recovery, even in a human-dominated landscape. This recovery, was probably facilitated by local pastoralist traditions, which combine vigilant herding of livestock with little or no hunting of wild prey. This success might be replicated in other areas where traditional pastoralism is still practised.'

Significantly unlike the Serengeti- Mara *Lycaon* population no vaccinations of wild dogs are reported to have taken place in this northern Kenyan population despite the frequently claimed potential treat of rabies and CD to *Lycaon* from contact with similar local Maasai pastoralist's domestic dogs in southern Kenya and Northern Tanzania - the only areas were rabies vaccination of free living *Lycaon* have taken place to date.

This suggests that what may be termed a *'Bo-Peep strategy'* should be in future be applied by *Lycaon* research - leave them alone and they will come home Demographic research monitoring involving observations at a distance and photographic methods only appear to be quite adequate.

“History can offer perspectives that we would not otherwise have, and case histories of endangered species programs have the potential to serve as a corrective for past mistakes. This tool is diminished if accounts are not chronicled accurately.” **Ken Alvarez ,‘*Twilight of the Panther:* Biology, Bureaucracy and Failure in an Endangered Species Program’**

"If such a mess can be made of efforts to save a creature as attractive as the black-footed ferret in a country as well organized and prosperous as the United States, prospects for conservation in other parts of the world are indeed bleak." **Robert May *Nature* 1986**

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Appendix 1. **Cause of death in some of handled free living and captive packs**

Location	date	type of pack	type of handling r.c.	vaccinated	events following & n. packs or individuals.	cause
Zimbabwe(π)	1986	captive	?	no data	pack died	rabies
Serengeti	1985-90	free living	yes	no	5 packs died	*rabies
Mara	1987-90	free living	yes	yes	3 packs died	rabies
Serengeti	1991	free living	yes	yes	5 packs died	**rabies
Namibia (Etosha)	?	captive	?	yes	6 of 7 pups died (Vanguard live vaccine)	CD
	1989	introduced	? fitted with contraceptive implants	?	all 5 died	lions
	1990	captive	?	yes	all 11 died	lions(6) rabies(4) 1?
Botswana i. Moremi	1996	free living	***yes	?no	5 packs died in 3 weeks	?CD/ rabies
ii.Chobe	1994	free living	no data provided		10 of 12 died in 2 weeks	CD
South Africa i. Madikwe	1997	introduced	yes	yes	7 of 10 died or 'put down'	rabies
	2000	introduced	adult yes	ad. yes pups no	8 of 11 pups died	rabies
South Africa ii Kruger	1995 -2000	free living	yes but adult pair in each pack immob./ blood sampled n=72	no	pop. decline of 60%& 30% of packs lost	unknown
Mkomazi (Tanzania)	2000-1	captive	no	yes CD$ rabies etc	49 of 52 died in 4 packs in 2 months	CD
Zimbabwe (Hwange)	2003-	free living	rc	no	1 female died	rabies

π. Kat et al (1995) claims that this pack was unhandled.
* Confirmed in a tissue sample from the *only* pack from which an adequate sample was taken
**. No tissue samples taken but 2 Mara packs died in December 1990 one with rabies confirmed
*** All radios expired within 19 months, dogs re-immobilized to replace. No tissue samples from 5 dead packs.
CD= Canine Distemper:- despite serological evidence of high levels of exposure of free living packs to the virus in Botswana, Selous, South Africa and Namibia, the only reported case of CD in free living wild dogs was in Botswana in 1994 when 10 individuals in a pack died; whether the pack was handled is unclear.
$ Inactivated CD vaccine used (van de Bildt et al 2002) cf. Etosha.
r.c. =radio-collared

Appendix 2a **Photographic surveys and information from rangers provides reliable indications of size and changes in populations of wild dogs without the use of telemetry.**

i. In Serengeti :- In the period 1965 to 1971, 163 different dogs (age not known) were photographed and catalogued on the Serengeti plains (van Lawick- Goodall 1970) at a time when the population was claimed to be small but stable. This is comparable with the 166 different individuals in 13 different packs photographed in another 6 year period (1985-91 see Table 1) at a time when the wild dog population of the plains was claimed to be very low compared with that in the late 1960s and 1970.

Of the 13 packs photographed between 1995-91a maximum of 5 packs *were seen in any one year and that was in* early 1991 when the same number of packs were present as, *based on published data* (Appendix 4).as were on the plains *in 1970.* This was despite what was claimed to have been :-

a. a terminal decline in the Serengeti population starting in 1970 (Ester 1991)
b a claimed series of population crashes (Creel 1992, Ginsberg 1995b) before handling began in the Serengeti.

and despite :-
c. the confirmed low reproductive success of plains study pack in the 1970s

d the extinction of 5 whole study packs 1985 -1990.

It must be concluded that prior to 1991 there is no evidence for a significant change in the wild dog population resident on the Serengeti plains from 1964-91 (Burrows et al 1994).

TABLE 1. Confirmed numbers of wild dogs photographed 1985-91 on the Serengeti Plains in 13 different packs and 6 groups. There were 166 *different* individuals
P=Packs; bip =born in pack; emi = emigrating groups; m=male; f=female

Pack/Group	**n seen**	**'new' dogs**
Plains P	37	37
Naabi P	7	3
Naabi bip	33	33
Pedallers P	13	10
Salei P	4	2
Salei bip	18	18
Ndoha P emi. f.	5	0
emi. m. 4 & 3	7	7
Barafu P	2	0
Lemuta P	3	2
Aitong f.	5	5
Mountain P	7	7
bip	13	13
T.Blazers P	6	0
2m	2	2
2f	2	2
Moru Track P	7	7
Ndutu P	17	13
N.Barafu P	6	0
3f.	3	0
Gardner P	5	5
M&S P	2	0
Totals	**204**	**166**

ii. **In Kruger.** As a result of a wild dog photographic competition tourists provided information which enable a 60% decline in the population between 1995-2000 to be detected when telemetry apparently to have failed to do so (M.G.L. Mills.< www.parks-sa.co.za/conservation/scientific>).

iii. In Selous estimates of the size of the population provided by rangers and game scouts before handling began in this woodland habitat in 1991 proved to be a reliable and were later confirmed by radio- telemetry (Creel & Creel 1994).

Data collection using faecal analysis

DNA studies of free living wild dogs and other species using faecal samples from known individuals of known social status can produce valuable results on relationships of individuals (K. Leigh per comm.) It is also possible to measure changes in hormone levels (Creel et al 1997 ,East et al 1997, Hofer & East 1998, Goymann et al 2001).

Appendix 2 b. Number of packs and individuals claimed on the Serengeti plains in the late 1960s and the claimed series of population crashes is based on a misinterpretation of data:-

Estimate of the population of wild dogs for the 'ecological unit' based on observation on the plains pre 1970.

Schaller studied lions on the plains of Serengeti between December to May each year a period co-incident with the denning period of the wild dogs when the packs are most easily observed but in the dry season worked primarily in woodland (Schaller 1972). Serengeti packs travel widely over their extensive home ranges during the dry season and are difficult to locate and to follow as they often long distances at night (Burrows 1995). Schaller thought that the wild dogs left the plains and retreated with their prey *into* the woodlands during the dry season. This was not the case and no woodland dwelling packs were every observed (see above). The invaluable data which Schaller produced including his estimated population densities therefore must relate mainly to wild dog packs and groups on the open plains in the wet season.

Schaller's PD in Table 1 (above) is derived from an estimate that between June 1966-September 1969, 200-250 dogs, (including older pups not at dens which made up 1/3 of the population) existed in any one year in 'Serengeti'. This was for estimated PD for *the ecological unit* which at that time was 25,500km 2 an estimate with which Malcolm (1979) agreed but claimed applied also in 1970, *but to the number of adults so implying a sudden sharp rise*. Both Schaller & Malcolm based their population estimates on their knowledge the PD on the SE Serengeti plains

In his Table 65 Schaller (1972) reported that a total of 33 'packs' of differing composition seen during the period 1966-69 on the Serengeti plains but:-*" As packs changed their size and composition it was difficult to recognise some after a lapse of a few months"* and as a result:- "*Some individuals may have been counted several times….* (Schaller 1972 p 324). Schaller included single sex groups in his tally of 'packs'.

As Schaller reported, a healthy wild dog pack changes its composition frequently. This is due to successful reproduction, frequent emigration plus some immigration and mortality. There were not 33 different packs present on the plains between 1966-69. Just 5 packs were known in 1964 and 1967 and wild dogs were described as 'rare' . In his Table 56 Schaller provides 15 examples of different pack compositions, including that of 13 'groups' with a basic 'pack' structure (i.e. a potential breeding unit of at least one adult pair) and 2 single sex groups. In the *sample* he selected there were 153 individuals :100 adults and 53 older pups (6-12 mo.) as this was a period of high reproductive success. (see Table 1 where during the period which followed the claimed 'terminal decline' a similar number of dogs were still present)

Schaller did not identify each dog in each pack located and it later became apparent that data from at least 1 pack (the Genghis) was included for both 1966 and 1967. Schaller's Table 65. How many packs and thus number of individuals in them, other than in the Genghis Pack, were multiple counted in this way in Table 65 is unknown. Unless each individual is know and checked with photographs from both sides multiple counting of wild dogs is a common problem.

However, in both 1964 and 1967 there were 5 known 'packs' (one in 1967 consisted of young females only - i.e. not a true pack) on the Serengeti plains. Wild dogs were described as scarce and rare judging by the infrequency with which they were seen but the population up to September 1969 at least described as stable with no oscillations and had changed little since the 1950s (Kuhme 1965, Schaller 1972). Between 1965-69 based on the number of adults and older pups (comprising 1/3 of the population) the population density (PD) was 10-12 per 1000 km2 of *which 7-8 were adults* (data based on Schaller 1972 see Table 1).

Appendix 2 c. **Number of wild dogs and packs on the Serengeti plains in 1970**

For 1970 in a similar Serengeti plains area to that observed by Schaller it was reported that there were 12 pack and 95 adults in a 3000 km2 study area, *(Malcolm 1979, Frame et al 1979),* a PD of 28-29 *adults* per 1000 km2 and so an apparent population explosion between 1969-70 *with a near tripling of the adult population, and more than double the number of packs present on the plains in the late 1960's.* Clearly this need to be explained.

For 1970, a then young and experienced field worker based near Lake Lagarja, Ndutu just South of and outside Serengeti National Park who followed one particular pack (the Genghis which was the subject of a film). Working within a very limited area around Ndutu it was claimed that in 1970 there were over 100 adults and 12 packs on the Serengeti Plains (Malcolm & van Lawick 1975, Malcolm 1979).

The first mention of 12 packs on the Serengeti plains in the literature was in 1975:-

'*There are no less than 12 packs of wild dogs which may occasionally include the short grass plains around Lake Lagarja, in the Serengeti as part of their nomadic circuit"* (van Lawick 1973 p 10). van Lawick does *not* claim these were all seen in any one year. [These 'packs' included single sex dispersing groups]

The number of packs and adults in 1970 was later 'revised' to 77 adults in 10 packs plus one all male group. These revised data include *at least 30 unknown individuals* who were only seem once or twice, not catalogued and not resident year round in the area and included unpublished data for 2 other packs which contain another 10 adults (J Malcolm per. comm. & see this Appendix 4).

Of the 10 packs reported to have been seen in 1970, *just 4 were known to be resident (i.e. denning) in the 3000 kms2 study area*. Of the 3 PACKS which bred in 1970 one was a lone pair which split away temporarily from another pack (the Genghis). No pups born in 1970 are known to have survived.

Neither Schaller nor van Lawick reported the presence of 12 packs in any one year.

Later it was reported that between 1967-1972, twelve packs were *identified* (Malcolm 1979). There were therefore a maximum of 12 packs which were identified and named and in some of these packs all the individuals were catalogued *during that 5 year period* not in 1970.

For 1970 data is given relating to a maximum of 5 packs on the plains included a lone pair from a larger pack a resident all male group and a newly located pack whose denning area was unknown i.e. a maximum of 5 potential denning packs in 1970 (Frame et al 1979 see also Appendix 4).

Unfortunately Schaller's data and van Lawick's anecdotal statement relating to 12 packs has been misinterpreted and this is most probably the basis for the anecdotal claim that 12 packs and 95 adults were living year round on the Serengeti plains *in 1970* in a 3000 km2 study area. (Malcolm 1979, Frame et al 1979). There is no data evidence for this claim.

Appendix 2 d. **Based on misreading of field data and anecdotal statements a number of erroneous or misleading statements commonly appear:-**

1. In the late 1960s ..*"some 153 wild dogs ranged the Serengeti Plains"*. The reference given is Schaller 1972 i.e. Table 65 (Estes 1992 p 413). Estes implies that there were 153 individual adults present as residents on the plains in any one year. Schaller's Table lists 153 individuals seen *between 1966-69* some of which were counted more than once (see below). Schaller's total also contained 53 pups which were *not included* in the demographic data provided by researchers post 1969.

However based on this error of data interpretation Estes suggests that when the mean number of adults in the study packs fell to 3.6 in the late 1970s *the decline in the sub-population* may have been irreversible.

2. It is claimed that number of *adults living on the plains year-round* (i.e. resident) in 1970 was around 110 (Malcolm & van Lawick 1975 and pers. comm. to Hanby & Bygott 1979 in Sinclair &Norton-Griffiths 1979).

3. *"Wild dog have declined on the plains from over one hundred in the 1960s to only thirty in 1977"* (Sinclair & Norton-Griffiths p.13, 1979).

4. The population density for Serengeti wild dogs between 1967-79 is claimed to be 0.015 adults/km2 (Creel & Creel 1996). However Creel not only takes Schaller's estimate to be based on numbers of *adults* pre 1970 but also appear to take the highest figure as the basis for their calculation of PD up to 1970 i.e. 1 dog per 85 km2. Creel then take Malcolm's PD (in Frame et al 1979) for 1970 (1:35 adults/ km2) and Frame et al's PD data for 1977 (1:200 adults/km2) and average the results (see Table below)

Table Population densities estimates

Category of dog	**years(s)**	**1/km2**	**n/km2**	
adult plus older pups	**1966-69**	**1:85-102**	**0.012-0.009**	**Schaller (1972)**
adult	**1970**	**1:35**	**0.028**	**Malcolm (1979), Frame et al (1979)**
adult	**1977**	**1:200**	**0.005**	**Frame et al (1979)**
		Total	**0.0045**	
	Average 1967-78		**0.015**	**Creel & Creel (1996)**

Frame & Frame's data was based on a study area of 5,200 km 2 in which in 1977 they counted 26 adults. This was NOT the entire population of Serengeti NP/ or the ecosystem as is implied by some commentators. In 1976 it was claimed that there were at least 7 more packs in the areas around their study area (Frame &Frame 1976).]

These error have led to the totally unfounded claims :-

(i) for a terminal decline staring in 1970,
(ii) for a series of population declines
(iii) that increased competition amongst predators following the increase in the Serengeti lion and spotted hyaena population in the 1970s is causally related to the decline in the wild dog population in the 1970s.
(iv) that the plains were perhaps *no longer a suitable habitat* for wild dog (Sinclair & Norton Griffiths 1979).

All the above claims are all based on a misinterpretation of Schaller's Table 65.and the use of incorrect data for 1970 and are without any data basis

Despite the small revision in the 1970 data made by Malcolm, neither the magnitude of the error nor its influence on later thinking about Serengeti wild dogs and their future management has been appreciated.

Appendix 2 e. **A claimed terminal decline starting in 1970 a claimed crash in 1971-73**

No regular wild research was being carried out in Serengeti between 1971-74 and opportunistic records were collected mainly from a small area around Ndutu with months of little activity. Malcolm was present for just 3 months in 1971 and 2 months in 1972.

The highly inflated estimate of the number of wild dog adults claimed to be resident on the Serengeti plains in 1970 was later uncritically used as the basis for a putative Serengeti population crash between 1971-73 when it is claimed the population fell from 96-49 with 5 of 12 packs disappearing with disease implicated (Creel 1992, Creel et al 1997). The reference given is Malcolm (1973). No mortality data was collected from 1971-74. For the periods 1969-71 and 1974 - 79 annual adult survival was 0.825 and death was *inferred* from the disappearance of known single adult dogs. The lodge manager at Ndutu reported that a pack, unknown, was *'looking sick'* in 1971. An assumption that at this time that disease played a role in wild dog population regulation in Serengeti but *"the data are thin"* (J.Malcolm per comm).
There is no evidence either for the loss of 5 packs between 1971-73, or significant disease related mortality, but at least 3 packs which were not identified were shot in Serengeti, one in 1970 at the boundary of the National Park with a Game reserve, a second in 1972 when 25-30 were shot in the middle of the Park and in 1973 an entire pack was shot near Seronera (Malcolm 1979, Frame 1976).

It was not until 1974 that data was obtained from full time demographic research of wild dogs in Serengeti. In 1974 the resident Serengeti plains population, *in a 5,200 km2 study area*, was reported to be 49 adults in 7 packs (5 resident), a PD of 9-10 per 1000 km2 (Frame et al 1979). From 1974 there was a decline in mean adult group size but in 1977 there were still 7 packs again 5 of which were resident (see Appendix 3).

Later critical analysis of the published data and other research suggests that the most likely number present in the Serengeti plains 3000km2 study area in 1970 was around 30 resident adults in 4 -5 packs and so comparable with Schaller's estimate for the number of adults and breeding packs pre 1970 (Schaller 1972, Burrows 1995 and see Appendix 3).
The validity of the 1970 data is clearly incompatible with the claim that even in favourable habitats a reserve of 2,300 km2 could only support just 6 packs and a maximum of 30 adults. (Frame & Frame 1986, Fanshawe et al 1991).

This contrast starkly with the claimed 95 adults and 12 packs in a 3000km2 Serengeti Plains area in 1970 (Malcolm 1979). The Frames considered the Serengeti plains to be not good habitat for *Lycaon*

The poor reproductive success despite the large numbers of adults in some packs in the late 1960s was *before* the increase in hyaena and lion population took place and suggests a pathogen, possible canine distemper, was involved (see Appendix 1c). If competition from other predators was the cause of the decline in mean pack size in the 1970s, then extinction of the wild dog population might have been expected in the late 1970s when packs were very small, not post 1978 when reproductive success was high and the population expanding despite sporadic pack extinction(Fuller et al 1992, Burrows 1995).

Appendix 2 f . **A claimed Serengeti population crash in 1975-76**

Ginsberg et al's 1995 PVA model is based on what are claimed to be a series of significant crashes (>40%) in the 'Serengeti' population, the first in 1975-76 before intensive invasive handling began. This putative population crash 1975-76 from 60-30 adults, is crucial to the model but a closer examination of the published 1975-6 data (Frame et al 1979) of the yearly maximum number *of adults* in each pack seen in the study area does not support such a claim. The researchers involved also provided data on the study population per quarter year (see Table 2). It is clear that there were not 60 individual study adults recorded *at any one time* in the Serengeti study area in 1975.

Disease is claimed to be the cause of the putative crash in 1975-76 but no ailing dogs were seen in the Serengeti between 1974-77 and just 13 of 79 known adults died giving an annual survival 0.825 (Malcolm 1979, Burrows 1995). Deaths were *inferred* from the disappearances of single adult dogs (mainly age related see data in Malcolm 1979) excluding probable emigrants which also disappeared (Frame et al 1979, J. Malcolm pers. comm., Burrows 1995). The number of individuals seen in 1975 is based on *yearly counts of adults* and included a rare sighting of one large peripheral pack which did not den in the study area; when seen in late 1974 there were 4 adults and 11 pups present. *These pups were not included in the population count* but by the second quarter of 1975, as the pups were >12 months old, they were now counted as adults by the researchers. The pack appeared to rapidly expand from 4 to 15 adults (Appendix 3).

The apparent loss of individuals and 2 packs in 1976 was mainly due to the failure of the researchers to see two other peripheral packs which denned outside their study area. One was not seen again in the study area after the first quarter of 1975 when it had 3 members. The second a previously unknown pack containing 18 adults when first seen in August 1973. Its home range was not defined and its denning area unknown. When last seen this pack consisted of 12 adults (4 adults and 7 yearling males and a lone adult female). Five yearling females from this pack had emigrated to join an all male study group in January 1974. The pack was last seen in the study area in the first quarter of 1975. This gave the appearance from the *raw yearly data* that 2 packs and 15 individuals had died/disappeared. There is no evidence that they did. There were not 60 adults at any one time in the Serengeti study areas in 1975 with a maximum of 46 in 1975 (Table 2).

Table 2 Total verified population of *adult* wild dogs observed in the Serengeti plains study area 1974-76 (data from Frame 1977 Table 3 & Frame et al. 1979 Table 1). Data given at 3 month intervals.

		1974				**1975**				**1976**		
Frame 1977	**44**	**43**	**42**	**41**	**39**	**46**	**38**	**37**	**32**	**31**	**30**	**30**
n Packs		**6**				**7**				**5**		
cf Frame et al. 1979		**7**				***8**				**5**		
but give data for		***4 +1 amg***				***4 packs***				***5 packs***		

* Data provided for only 4 packs; 3 of which were peripheral packs rarely seen, and did not den in the study area. Frame & Frame's data was based on a study area of 5,200 km 2 in which in 1977 they counted 26 adults. This was NOT the entire population of Serengeti NP/ or the ecosystem as is implied by some commentators. In 1976 it was claimed that there were at least 7 more packs in the areas around their study area (Frame &Frame 1976).

As the researcher involved observed with reference to the Serengeti decline since 1975:-

" there are several reasons to suspect that the decline in the population is more apparent than real" (Frame 1977).

The pack is the basic reproductive unit in wild dogs and the size of the breeding population is directly related to the number of packs in the study population (Woodroffe & Ginsberg 1999). Despite the loss of 60% of the individuals in Kruger between 1998 and 2000 this is not regarded as a crash.

The claimed 1975/76 wild dog population crash is an artefact of data presentation. Ginsberg et al's PVA model based on a series of crashes *pre* and *post* the use of routine handling (i.e. 1985) is fatally flawed.

Appendix 3. Survival less than one year following handling data from Ginsberg et. al. (1995a) most mortality claimed to be due to 'natural causes'.

	% Radio -collared	% radio implanted	% blood sampled only
Botswana	25		33
Hwange	31		ND
Kruger	40	53	21
Mara (Kenya)	33		70
Selous (Tz)	20		ND

Appendix 4. Resident (i.e. denning), Peripheral (non denning) and unknown packs/groups of wild dogs on the South East Serengeti Plains 1969-77 (no data for 1972&73) pd = based on published data from Frame et al (1979) & Frame (1977). Data for 1971 James Malcolm (JM) pers comm.

YEAR	**1970a pd**	**1970b new data JM.**	**1971 J.M..& .pd**	**1972 -73 ND**	**1974 pd**	**1975 pd**	**1976 pd**	**1977 pd**
a. RESIDENT PACKS								
Genghis	16(7)	16(7)	9(2)		7(0)	10(4)	5(0)	4(0)
Genghis a.	2(0)	2(0)						
Genghis b.			2(0)					
$Herod=Flavian	7 (5)	7(4)	2(amg)					
Kuhme	ND	[5]	ND		5(0)	4(0)	5(0)	2 (0)
$Pimpernel=Nettle	4 (amg)	4(3)	6(0)					
$Cassidy=Seronera	ND	[5]	4(0)		7(0)	8(5)	6(0)	3(0)
Plains					3(0)amg	7(0)	5(0)	5(0)
Falcon								4
Packs (including resident amgs)	**4 3+amg**	**6**	**5 4+amg**		**4 3+amg**	**4**	**4**	**5**
Resident adults %(ylgs)	**29 54**	**39 36**	**23 9**		**22 0**	**29 31**	**21 0**	**18 0**
b.PERIPHERAL PACKS								
Plane a Plane b	8(10)	8(10)	9 5		ND ND			
Semetu					9(6)	3(0)	ND	ND
Spitfire					4(0)	15(11)	8(4)	4(0)
Simba					12(0)	**12(0)	ND	ND
peripheral packs	**1**	**1**	**0**		**3**	**3**	**1**	**1**
peripheral ad	**18**	**18**			25 (6)	30(11)	8(4)	4(0)
c. UNKNOWN PACKS & amgs [ ]number of adults	**0**	**a[4] b[9] c[7] [10] amg**	**0**		**0**	**0**	**0**	**d[3]**
unknown adults	**ND**	**30**	**0**		**0**	**0**	**0**	**3**
unknown packs	**0**	**3**	**0**		**0**	**0**	**0**	**1**
Total adults a+b+c % yearlings	**47 47**	**77 42**	**37 6**		**47 13**	**59 40**	**29 8**	**25 0**
Packs & amgs	**5**	**7**	**7**		**7**	**7**	**5**	**6**
. non resident amgs	**0**	**1**	**0**		**0**	**0**	**0**	**0**
TOTAL INDIVIDUALS a+b+c in year	**47**	**87**	**37**		**47**	**59**	**29**	**25**
TOTAL PACKS a+b+c in year	**5 4+amg**	**10 +amg**	**7 6+amg**		**7. 6+amg**	**7**	**5**	**7**
Compare above with:-								
individuals Frame et al	***95.***	***95***	***ND***		***49***	***62***	***29***	***26***
packs Frame et al.	***12***	***12***	***ND***		***7***	***8***	***5***	***7***

Figures in brackets:- ( ) yearlings; [ ] new unpublished data; **ND** =No Data; **amgs** = all male groups resident in a home range after the female(s) have left/died; $ Some packs were given different names by different observers.
Peripheral= packs which did not den in the study areas , JM = James Malcolm;
***** Plane 1969 with 10 pups. Adult sex ratio unknown, pack not catalogued; 10 pups approx. 6 mo in early 1970
****** No data for Simba pack in 1975 in Frame et al but possibly seen in first quarter of year (L.Frame 1977).
******* Frame et al 1979 (Table 1) claim 8 packs in 1975 but this is an error due to counting an all female group twice.
Unknown = packs/groups reported one or twice in study area in 1970 by J.Malcolm (pers comm.) but for which there are no published data (cf revised data of 87 in 10 packs and 1 amg. J.Malcolm pers comm. in Burrows (1995). Identity of 3 packs shot (1970-73) not known

Appendix 5. **Rinderpest as a possible factor in the 1970s decline in mean pack size**

A dramatic decline in the reproductive success of Serengeti wild dog packs in the late 1960s and the 1970s was coincident with reports of the death of wild dog pups with clinical symptoms suggesting Canine Distemper (CD) (Schaller 1972). In the 1960s Spotted hyaena were found to be seropositive for Rinderpest (RV) although no associated mortality was reported (Sachs & Staak 1966). The suspected CD in wild dog affecting mainly wild dog pups and young adults with no evidence of high adult mortality (contra Creel 1992). The successful vaccination of domestic stock against rinderpest in the 1950s led to the virtual elimination of the virulent strain of rinderpest virus from wild life by 1963. The viruses causing rinderpest and canine distemper are very closely related and exposure to rinderpest virus is known to provide cross resistance to canine distemper in domestic dogs, although with no serum antibodies reported (DeLay et al 1965).

It is conceivable that up to 1963 when rinderpest was common in Serengeti in young wildebeest and buffalo, wild dogs, like the Maasai's domestic dogs which ate meat from infected wildlife, were naturally immunised against subsequent exposure to the distemper virus which causes high domestic dog pup mortality. Such protection would have ceased within a few years of the rinderpest decline as wild dog females born post rinderpest failed to pass on maternal protection to their pups. This could have caused the observed decline between 1970-78 in the reproductive success of the Serengeti wild dog population and in other wild dog populations over a wide area, including the Mara (Appendix 3).

The sporadic re-emergence of rinderpest in domestic animals and wildlife in the late 1970s and early 1980s and the existence of sub-lethal strains in domestic stock (Dobson 1995) may again have provided protection for wild dogs and domestic dogs against canine distemper virus. This would explain the resurgence of the Serengeti-Mara population and other populations which occurred post 1978, following improving reproductive success. All blood samples taken between 1985-91 from Serengeti and Mara wild dogs were seronegative for exposure to canine distemper virus, the only confirmed disease related mortality during this period was from rabies.

It can be concluded that between 1970-77 *there was a non significant decline in the number of adults in the study packs* due to very poor reproductive success post 1969 but *no decline in the number of study packs resident in the study area*.(Frame et al 1979, Burrows et al 1994 & 1995 & see Appendix 3). Based on Schaller's data up to 1969 the resident Serengeti adult population in 1970 in a 3000 km2 study area was likely to be 21-24 this compares well with the 29 based on the published data for 1970 (see Appendix 3).

Given a wild dog packs ability to suddenly expand when conditions are favourable and the ability of a pack to exist for a number of years even without good reproductive success as in Serengeti in the 1970s the pack, rather than the number of individuals, should be taken as the basic unit of a wild dog population (Woodroffe & Ginsberg 1999). There is no basis for the claim that the Serengeti population was isolated or for the high population density claimed for the late 1960s and 1970 or for a significant decline between 1970-78.

APPENDIX 6 Numbers indicate sequence of Serengeti -Mara study pack extinction All study packs contained radio collared dogs

uv = unvaccinated packs.
v = packs containing vaccinated dogs
* radio-collar removed
? Fate of this unvaccinated pack unknown last reported in April 1991
italics = Mara Packs

Packs and date of extinction

1. Pedallars uv	June	1986	7.*Intrepids* v.	December	1990
2.Naabi uv	August	1988	8.*Ole Sere* v.	December	1990
3.*Aitong* v.	September	1989	9.Ndoha .v.	February	1991
4.Ndutu nv	November	1989	10.*T. Blazers* nv.	?April	1991
5.Lemuta nv.	February	1990	11.Salei v.	May	1991
6.Mountain nv.	August	1990	12.N. Barafu v.	June	1991
			13.M&S* v.	June	1991

TABLE 3 Sporadic pack/group deaths in Serengeti (n= 6) and Mara (1) post collaring 1986-90 .Other packs in same area survived. No individual in these packs/groups had been vaccinated.

Pack survival = survival in months from handling to last sighting or to first deaths r.c. = radio-collared
older = more than 2 years old. bs =blood sampled , ylg = yearling (M) = Mara Group

pack	**year r.c**	**age of dog**	**pack survival/**	**cause**	**comments**
Pedallars	1986	older male	<3	rabies suspected	dead & dying at den the empty r.c found.
Naabi	1988	ylg female	<4	unknown	the empty r.c. found pack had been exposed to rabies pre the r.c. event
Ndutu	1989	older male	<3	unknown	a female collared as ylg in Naabi pack was bs at same time the 2 empty collars found
Henry group	1989	older male	<3	unknown	left Ndutu Pack early 89 seen with another dog before empty collar found near 2 Ndutu pack collars
Buffalo (M) Girls	1989 females	dispersing	<3	unknown	sister survived as Ole Sere alpha female
Lemuta	1990	older male	<1	unknown	not seen again post collaring the 2 females in pack were from Aitong Pack (Kenya) vaccination status unknown.
Mountain	1990	older f. May old m. June	<3 <2	rabies	empty r.c. from f. found pups last to be seen alive as in Aitong pack 1989 rc m died underground

TABLE 4 Multiple handling of packs both at vaccination and for radio-collaring of individuals post vaccination. Survival of pack in months following last anaesthetization event in pack. All packs which became extinct contained vaccinated dogs ym = yearling male dart vacc= vaccinated against rabies by dart gun.

Pack	**year**	**age**	**survived months to first deaths**	**cause**	**n.vacc**	**comments**
Aitong	1989	3 pups	<2	rabies	>=4	pack part vaccinated since 1987 2 of the 3 r.c. pups were vacc. and 8 dogs anaesthetized for bs a few months pre pack death a vacc dog died from rabies
Ole Sere*	1990	?	<4	rabies	>=1	Rabid male was r.c as yearling in Ndoha pack in 1987. Collar battery ended early 1990.Male dart vacc in early 1990.
Interepids	1990	ym	<3	?	11/11	dead & dying dogs found no samples taken all pack members vaccinated
Ndoha	1991	ym	<1	?	12/12	a female collared and vacc adults in Oct 90 was unsuccessfully darted. Alpha male not seen post vacc in Oct 1990 empty collar found. pack not seen again post collaring
Salei	1991	ym	<3	?	9/9	pup r.c Feb 91 dart vacc Oct 90 the empty collar found. alpha male seen alone .

TABLE 5 Packs in which most individuals were vaccinated but not handled again post vaccination.

Ad = adults   , ylg = yearling r.c. = radio-collar ,vacc = vaccination

Pack	**year**	**age m**	**survived months**	**cause**	**n. vacc**	**comments**
Trail B	1991	*ylg	<6	?	6/6	2 empty r.c. found
New Barafu	1991	ylg	<6	?	5/8	neither collar found
M&S	1991	Ad	<=8	?	2/2	no collars when lost collar removed from old male Sept 90 when vacc.

* male in a group of 3 blood sampled in Nov 1990 before males joined 3 females to form pack