Department of **Agriculture and Fisheries**
Biosecurity Queensland

Invasive animal risk assessment

Serval hybrids

Hybrids of
Leptailurus serval (serval) and
Felis catus (domestic cat),
including the 'savannah cat'

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Front cover: Close-up of a 4-month old F1 Savannah cat. Note the occelli on the back of the relaxed ears, and the tear-stain markings which run down the side of the nose.
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Contents

Introduction

The common name 'savannah cat' is a poorly defined marketing name first used by a small number of professional cat breeders and tends to be applied to F5 hybrids derived from captive cross-breeding between wild African servals (*Leptailurus serval*) and domestic cats (*Felis catus*). Such animals are also referred to as 'serval hybrids', 'American savannah cats' and 'designer cats'.

This assessment is relevant to all hybrids of servals and domestic cats, but is predominantly focused on the F5 hybrid 'savannah cat'.

Serval hybrids, including the so-called 'savannah cat', are classified according to a filial number (the number of generations that a particular animal is removed from the original serval breeding stock), as follows:

F1 hybrid is the progeny resulting from breeding a female domestic cat with a male serval.

F2 kittens are derived from F1 females mated to a male domestic cat that has morphological attributes considered 'desirable' by the breeder. Desirable attributes include 'long neck, large ears set high on the head, long, lean and tall body and a beautiful clear coat' (Sand Hollow Savannahs 2008).

F3 kittens are the result of breeding an F2 female with a male domestic cat (again selected for its 'desirable' traits).

F4 kittens are the offspring of an F3 female and a 'desirable' male domestic cat.

F5 kittens are the offspring of an F4 female and either an F4 male or a domestic cat male. Male F4 hybrids are the first generation of males that are not fully sterile; F5 and later generation hybrid males are usually fully fertile and can thereafter be used for further breeding (Gaines 2004).

Filial number does not indicate the percentage of serval genetic material contained within a particular animal. Some breeders back-cross savannah cats with servals (as opposed to domestic cats) which results in later generation savannah cats (such as F5) having a higher 'percentage' of serval genes (Miller 2002). It is not possible to scientifically measure the percentage of serval genes in a particular savannah cat.

While the savannah cat was recognised as a breed by The International Cat Association in 2000 (TICA 2004), it has not been recognised as a breed by the Cat Fanciers' Association (CFA 2005). TICA recognises different breeds resulting from domestic-wild crosses as domestic cats, including the Bengal, the Chausie and the Savannah cat breeds. The president of the American Cat Fanciers' Association commented: 'we do not want to support designer breeds for the fad pet market' (New York Times, 12 May 2005).

In the USA, the name 'savannah cat' is used interchangeably for all filial levels of serval-domestic cat hybrids and the TICA-recognised breed.

Identity of taxa under review

	Serval	Domestic cat
Class	Mammalia	Mammalia
Order	Carnivora	Carnivora
Family	Felidae	Felidae
Subfamily	Felinae	Felinae
Genus	*Leptailurus*	*Felis*
Species	*serval*	*catus*
Author	Schreber 1776	Linnaeus 1758
Synonyms	*Felis serval, Caracal serval*	*Felis silvestris, Felis domesticus, Felis silvestris catus, Felis silvestris domesticus, Felis catus domesticus*

For many years there has been disagreement on the appropriate nomenclature and classification applicable to the Felidae (cat family) due to the relatively recent evolutionary diversification (speciation) within the family and resulting similarities in morphology and genetics. It is generally accepted that felids can be split into two subfamilies: Pantherinae, which includes all the big cats (*Panthera* spp., lion, tiger, leopard and clouded leopard); and Felinae which includes all the other small and mid-sized cats including the cougar, cheetah, lynx, caracal, serval, wild cats and the domestic cat (Wilson and Reeder 2005). However, over the past three decades a body of evidence has emerged on the exact nature of the Felidae phylogeny; that is, the true relatedness between the various species.

The phylogentic relationships among the Felidae were traditionally studied on the basis of physical morphology, but more recent studies have included both morphological and molecular techniques, including karology (Wurster-Hill and Centerwall 1982; Modi and O'Brien 1988), the genomic occurrence of two felid endogenous retroviruses (Benveniste, RE and Todaro 1974; Benveniste, RE et al. 1975; Reeves RH 1984); albumin immunological distance (Collier and O'Brien 1985); comparative morphology (Salles 1992); allozyme electrophoresis (O'Brien et al. 1987; Pecon-Slattery et al. 1994); two-dimensional protein electrophoresis (Pecon-Slattery et al. 1994); and chemical secretions from scent glands (Bininda-Emonds et al. 2001). Other recent studies have focused on the use of mitochondrial genes such as 12S RNA and cytochrome b (Janczewski et al. 1995); or the analysis of Restriction Fragment Length Polymorphism (RFLP) of mitochondrial sequences (Johnson et al. 1996); or 16S rRNA and NADH-5 (Johnson and O'Brien 1997); or combining analysis of the sequences of four genes (12S rRNA, 16S rRNA, NADH-5 and cytochrome b) with morphological and karological characters (Mattern and McLennan 2000) to produce phylogentic trees of the Felidae. Non-coding segments of DNA (introns and SINEs) within Y chromosome genes Zfy and Zfx (Pecon-Slattery and O'Brien 1998); segments within single-copy X-Y homologs SMCY, UBE1Y, and ZFY (Pecon-Slattery et al. 2004) have also been used to create felid phylogenies. These analyses have identified eight major felid lineages, although their chronology, branching order and exact composition were not until recently definitively resolved, in part because not all species were included in each of these earlier analyses.

The recent sequencing of the complete cat genome (see O'Brien et al. 2008 for a review) has allowed for extensive genetic comparisons across all of the Felidae. These studies have cumulated in the analysis by Johnson et al. 2006, which included sequences from 19 autosomal, 5 X-linked, 6 Y-linked and 9 mitochondrial gene segments across the 37 extant felid species (Figure 1).

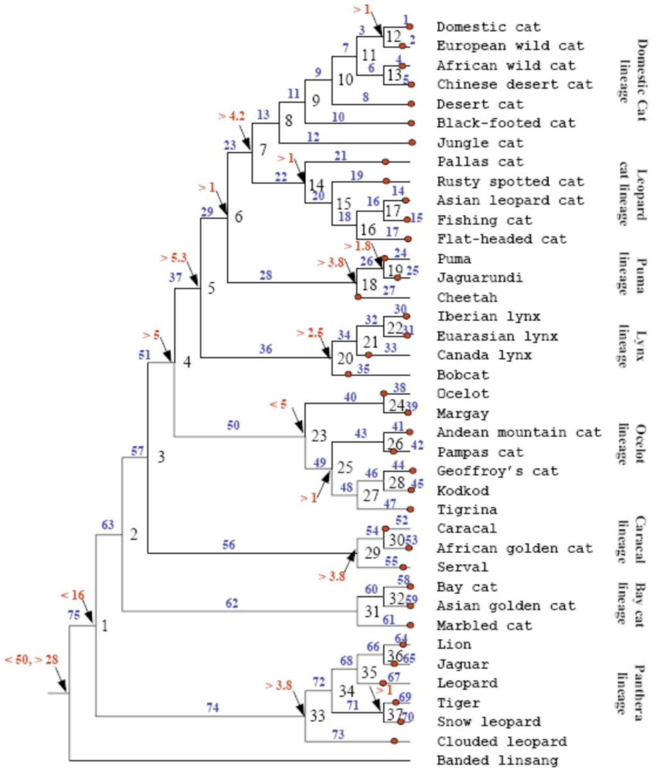

Figure 1. Felidae phylogenetic tree from Johnson et al. (2006)—supporting material available from http://www.sciencemag.org/cgi/content/full/311/5757/73/DC1.

The eight lineages as elucidated by Johnson et al. (2006) (in order of divergence) are:

- Panthera lineage (subfamily Pantherinae: *Panthera* spp. and *Neofelis nebulosa*)
- Bay cat lineage (subfamily Felinae: *Pardofelis* spp.)
- Caracal lineage (subfamily Felinae: *Caracal* spp.)
- Ocelot lineage (subfamily Felinae: *Leopardus* spp.)
- Lynx lineage (subfamily Felinae: *Lynx* spp.)
- Puma lineage (subfamily Felinae: *Puma* spp. and *Acinonyx jubatus*)
- Leopard cat lineage (subfamily Felinae: *Prionailurus* spp. and *Otocolobus manul*)
- Domestic cat lineage (subfamily Felinae: *Felis* spp.).

The caracal lineage, which includes the serval, diverged from the lineage leading to domestic cats approximately 8.5 million years ago. The leopard cat lineage, which includes the Asian leopard cat, *Prionailurus bengalensis*, diverged from the domestic cat lineage approximately 6.2 million years ago (Johnson et al. 2006).

The present-day domestic cat, *Felis catus* is descended from the North African wildcat *Felis silvestris lybica* that was domesticated in Egypt and the Near East more than 10 000 years ago and through mutation and selection has become the modern domestic cat. Randi and Ragni (1991) suggested that *Felis silvestris* be regarded as a polytypic species with the domesticated form (*Felis silvestris catus*) and three wild subspecies: African wildcat (*F.s. lybica*), European wildcat (*F.s. sylvestris*) and Asian wildcat (*F.s. ornata*). Driscoll et al. (2007) suggested that *Felis silvestris* consists of at least five subspecies: near eastern wildcat (*F.s. lybica*), European wildcat (*F.s. silvestris*), Southern African wildcat (*F.s. caffra*), Central Asian wildcat (*F.s. ornata*) and Chinese desert cat (*F s. bieti*), and that *Felis catus* can be grouped most closely with *F.s. lybica*.

Over its wide distribution *Felis catus* is known to interbreed and hybridise naturally with the other subspecies of *Felis silvestris*. There is debate over the conservation significance of hybrids of the species *Felis silvestris* as a whole. Hybridisation and introgression was widespread in Scotland (Beaumont et al. 2001) and Hungary (Pierpaoli 2003) but hybrids occurred only rarely in Italy (Randi et al. 2001). There is significant conservation concern for isolated relict populations of *Felis silvestris silvestris* in Portugal (Oliveira et al. 2008) and Scotland (Joint Nature Conservation Committee 2007) since genetically pure specimens may no longer exist.

Man-made hybrids of *Felis catus* have been reported (or claimed to have been created) for a number of species within the subfamily Felinae (Hartwell 2007) (Table 1). These were either zoo 'accidents' or deliberate attempts to create founders of new domestic cat breeds. Some of these new breeds have been developed to the extent that they are now recognised by some of the world's leading cat showing and breeding registries. These hybrid breeds have in turn been hybridised with other species in the Felidae to create even more breeds (Table 2).

Table 1. Felinae species that have hybridised with the domestic cat *Felis catus* (after Hartwell 2007)

Species	Hybrid (breed) name	Location and date of breed development	Lineage as per Johnson et al. 2006
Jungle cat *Felis chaus*	Chausie, (Jungle curl, Stone cougar)	USA 1995	Domestic cat
Black-footed cat *Felis nigripes*	—	—	Domestic cat
Leopard cat *Prionailurus bengalensis*	Bengal Pantherette Ussuri	USA 1963 USA 2000 —	Leopard cat
Rusty-spotted cat *Prionailurus rubiginosus*	—	—	Leopard cat
Fishing cat *Prionailurus viverrinus*	Machbagral Viverral	USA 2001	Leopard cat
Jaguarundi *Puma jaguarundi*	—	—	Puma lineage
Manul *O. manul*	—	—	Puma lineage
North American lynx *Lynx canadensis*	—	—	Lynx lineage
Bobcat *Lynx rufus*	—	—	Lynx lineage
Geoffroy's cat *Leopardus geoffroyii*	Safari	USA 1980s	Ocelot lineage

Table 1. Felinae species that have hybridised with the domestic cat *Felis catus* (after Hartwell 2007) (cont.)

Species	Hybrid (breed) name	Location and date of breed development	Lineage as per Johnson et al. 2006
Margay *Leopardus wiedii*	Bristol	USA 1980s	Ocelot lineage
Oncilla *Leopardus tigrinus*	—	—	Ocelot lineage
Serval *Leptailurus serval*	Savannah	USA 1997	Caracal lineage
Caracal *Caracal caracal*	—	—	Caracal lineage

Table 2. Hybrid cats used in further hybridisations (after Hartwell 2007).

	First cross	Breed name	Second cross	New breed name
Felis catus	*Prionailurus bengalensis*	Bengal	*Prionailurus viverrinus*	Machbagral, Viverral
Felis catus	*Prionailurus bengalensis*	Bengal	*Leptailurus serval*	Savannah
Felis catus	*Prionailurus bengalensis*	Bengal	*Felis chaus*	—
Felis catus	*Prionailurus bengalensis*	Bengal	*Leopardus geoffroyii*	—
Felis catus	*Prionailurus bengalensis*	Bengal	*Lynx canadensis*	—
Felis catus	*Prionailurus bengalensis*	Bengal	*Lynx rufus*	—
Felis catus	*Felis chaus*	Chausie	*Felis silvestris silvestris*	Euro-Chausie
Felis catus	*Felis chaus*	Chausie	*Lynx rufus*	—

Early generation savannah cats typically exhibit some degree of hybrid inviability. Male savannah cats often retain larger size and are usually sterile until the F5 generation, although females are fertile from the F1 generation onward (All About Spots 2007). Reputed fertile F4 males are being used in breeding programs in the USA (King 2008b, Stucki and Stucki 2008). Since back-crossing of savannah cats to servals is known to occur, it could be expected that fertility at F4 should increase and possibly even appear in F3 as it did in the Bengal cat breed.

Identification of hybrids

To the untrained eye, some cat breeds are not easily distinguished from each other or from their later generation hybrids. Breeds developed from the serval include spotted-tabby oriental shorthair, Egyptian mau and the ocicat. All these breeds have a spotted coat. Identification on morphological grounds may be problematic. Most breed-registered cats in Australia are now micro-chipped when registered with the cat breed registries. Reading of their microchips and consulting 'registration' papers and/or registry databases should correctly identify most domestic cat/serval hybrids look-alikes. However, the 'registration papers' would need to be confirmed with the issuing registry. Re-chipping for the purpose of evasion of identification is possible. This is where the registered microchip of an animal is removed and another microchip from a legitimately registered animal of a similar looking breed is substituted. DNA testing might be used to identify an unchipped or suspected rechipped animal.

Species-specific mitochondrial DNA markers are routinely used in forensics (Melton and Holland 2007) and field population studies to confirm the species of origin of hair or scat samples (Fernandes et al. 2008). The mitochondrial DNA sequences are known for all the Felidae, e.g. 16S rRNA and NADH-5 (Johnson and O'Brien 1997; Johnson et al. 2006). However, the utility of this technique is limited in the case of hybrids as mitochondria are inherited on the maternal line. The breeding program for the savannah cat purports to start from a female domestic cat, so unless some back-crossing to a female serval has occurred, all domestic cat/serval hybrids should only carry *Felis catus* mitochondria.

Currently, the only commercial DNA-testing available for cats is a 'DNA Parentage Verification' test, which can provide information on the parentage of a particular cat. As currently offered, this test costs $130 for dam, sire and offspring plus $35 for each additional cat. This test is based on a panel of microsatellite markers (Lipinski et al. 2007; Menotti-Raymond 2005). To authenticate parentage of an individual, samples of the DNA of both parents are also required (Animal DNA Laboratory 2008). To use this commercial DNA test to confirm the parentage of a particular cat to five generations would require DNA samples of all the sixty-three animals in the cat's pedigree (i.e. the animal in question, its parents, grandparents back to great-great-great grandparents) and cost $2230. This test does not directly identify the breed or species. There is also a validated forensic version of this test (Menotti-Raymond et al. 2005; Coomber et al. 2007) suitable for evidentiary samples.

There is an alternative genetic approach that can be used to infer whether an individual animal belongs to a species or breed or is a hybrid of such. As an inference-based approach it would not necessarily stand up to evidentiary requirements. This approach uses a Bayesian model-based clustering algorithm called STRUCTURE (Pritchards et al. 2000) that identifies (K) genetically distinct subpopulations on the basis of the allele frequency at each microsatellite locus. The STRUCTURE algorithm additionally provides an estimation of the proportion of an individual's genome (Q) that originates from each of the K subpopulations. This approach has been used for the identification of hybrids of domestic cats *Felis catus* and European wild cats *Felis silvestris silvestris* (Randi et al. 2001, Italy and South Africa, 128 cats, 12 loci; Pierpaoli et al. 2003, 336 cats, Europe wide, 12 loci; Oliveira 2008, Portugal, 98 cats, 12 loci). It has also been used with large data sets of domestic cats to differentiate known breeds and post priori assign cats to these breeds e.g. Lipinski et al. 2008 who genotyped thirty-eight microsatellites in 1176 cats across 22 breeds and 17 random-bred populations; and Menotti-Raymond et al. (2008) who genotyped eleven microsatellites in 1040 cats across 38 breeds.

In their study, Menotti-Raymond et al. (2008) linked the Bengal cat and Ocicat on the basis of the proportion of shared alleles algorithm from composite genotypes (Figure 2a) and could not separate the Egyptian Mau from the Bengal on the basis of STRUCTURE defined populations (breed group 8, Figure 2b).

A technical requirement for this Bayesian approach to work is the availability of a panel of microsatellites that amplifies all loci for both the serval and the domestic cat. Lipinski et al. (2007) reported that some of the international parentage and identification panel of markers had null alleles in the Asian leopard cat and serval cat hybrids. It would also require access to one of the above-mentioned large data sets, with inclusion of minimum sets (n = 27) of known servals from the USA, and known cat/serval hybrids (n = 27) from the Savannah breeding program in the USA. The Menotti-Raymond dataset already includes the Bengal, ocicat, oriental shorthair and Egyptian mau, but the Lipinski dataset would also require the addition of Bengal, ocicat and oriental shorthair samples (n = 3 × 27 = 81).

It is unlikely that owners of cats of these breeds would make DNA available if it were to lead to the seizure and destruction of animals and prosecution of owners and/or importers of the Savannah breed.

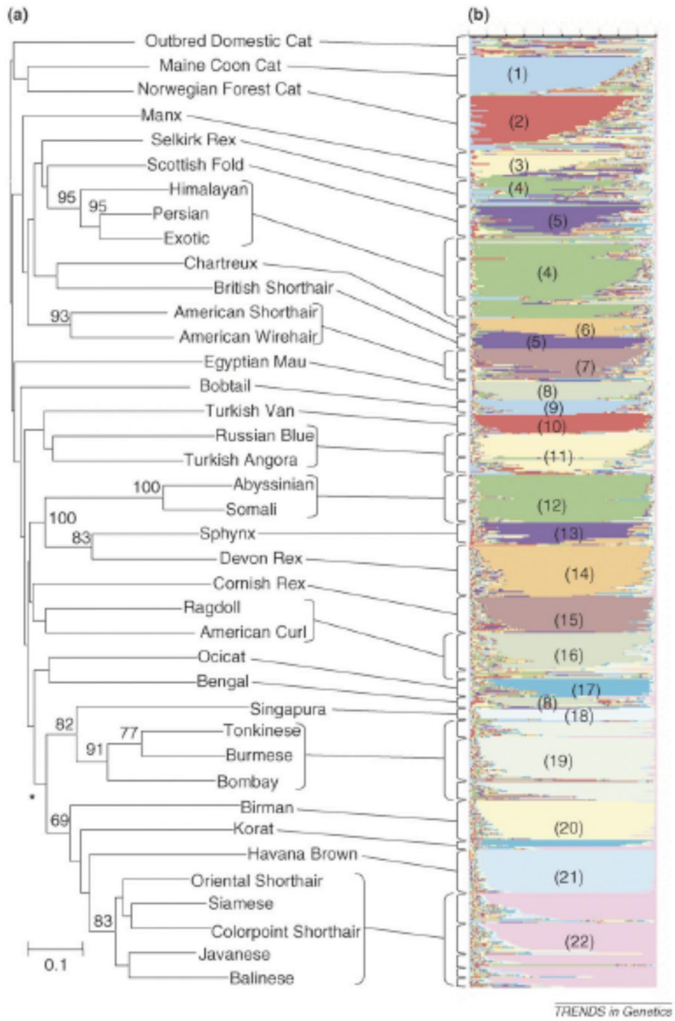

Figure 2. Phylogenetic neighbour-joining tree for individuals from 38 cat breeds based on distance matrices generated from the proportion of shared alleles algorithm from composite genotypes (column a). The histogram (b) generated from STRUCTURE analysis of 1040 cats showing shows the proportion of each individual's genome that originated from 22 populations (from O'Brien et al. 2008).

Description

Morphologically, the F5 hybrid savannah cat shares features of both the domestic cat and the wild serval, from which it was developed. A savannah cat's face is somewhat more triangular than a common domestic cat and its ears are exceptionally large, and positioned high on the head. Compared with an ordinary domestic cat, the savannah cat has a long, lean neck and long, slender legs, with elongated toes. The back legs are slightly longer than the front legs. Fur colour is variable, with various combinations of black, brown spotted tabby, silver spotted tabby and black smoke. The coat pattern comprises large, dark spots and other bold markings, which closely resemble the wild serval. The savannah cat can perhaps be described as a smaller replica of the serval (Breed standard—TICA 2008).

There is significant genotypic variation in savannah cats, with variation in size, even within a single litter. F1 males (first generation crosses between the wild serval and a domestic cat) can weigh from 8–11 kg, stand 40–45 cm tall at the shoulder, and have a body length (chest to rump) of 55–60 cm. F4 and F5 males can weigh from 6.3–8.2 kg, stand 32.5–38 cm tall, and be 40–45 cm long. Females are slightly smaller (Hummel 2007). There have been reports of male savannah cats weighing more than 18 kg (All About Spots 2007).

Biology

Life history

Gestation period: 63 days for domestic cats and 73 days for servals—because of the difference in gestation periods, early generation savannah cats are often born prematurely.

Young per birth: 1–2 for F1 savannah cats (Sand Hollow Savannahs 2008)

3–5 (average) for other generations (Krautheim 2007)

Birth interval: Not known exactly—breeders generally limit their animals to two litters per year. Savannah cats can breed again 4–5 weeks after giving birth. Ordinary domestic cats can produce 2–3 litters per year (Pet-Yard.com 2007)

Weaning: 8–12 weeks (Gaines 2004)

Sexual maturity: Not known exactly

7–12 months for ordinary domestic cats (Pet-Yard.com 2007)

18–24 months for servals (Webber 2004)

Sexual activity: Not known

Life span: Not known but thought to be comparable to ordinary domestic cats (c. 15 years) (Krautheim 2007)

Savannah cat breed history

The first savannah cat was born on April 7, 1986 in the USA, when Ms Judee Frank was able to crossbreed a serval with a domestic cat. One of the kittens from this animal was later purchased by Mr Patrick Kelley, who then decided to establish the savannah cat as a recognised new breed of cat. Another breeder (Ms Joyce Sroufe) worked with Mr Kelly to further develop the savannah cat breed. The International Cat Association (TICA) did not accept the savannah cat as a recognised breed until 2000 (All About Spots 2007). By 2005, TICA had registered 1023 savannah cats, all of them non-neutered (TICA 2005).

The savannah is not a currently recognised breed with either of the two national cat breeding and showing bodies in Australia (Co-ordinating Cat Council of Australia (CCCA) and Australian Cat Federation Inc. (ACF)) or with their four affiliated associations in Queensland (Queensland Feline Association Inc (QFA); Queensland Independent Cat Council Inc (QICC); Feline Control Council of Queensland Inc (FCCQ); and Council of Federated Cat Clubs of Queensland (CFCCQ)). However, if the breeding of savannahs becomes established in Australia, the major associations will probably recognise the savannah breed, as they have previously done for Bengal hybrids.

Behaviour

Savannah cats are very active and can leap 2.5 m high from a standing position. Wild-type behaviour can be observed in early generation or non-socialised savannah cats. For example, they may hiss and growl at strangers. They also make noises similar to a serval, such as chirping and loud hissing (Winchester 2008).

Diet

Savannah cats have no special health care or dietary requirements. All cats are obligate carnivores and since they cannot synthesise sufficient amounts of the essential amino acids taurine and arginine from other amino acids, they acquire arginine and taurine from animal tissue protein sources. Some breeders recommend a partial or complete raw diet with at least 32% protein and no by-products (Ward-Osborne 2007).

In Africa, servals are a generalist predator feeding on lizards, snakes, frogs, small birds (quails, quelea, teal), insects, fish, ground squirrels, hyraxes, mole rats, domestic poultry, small antelopes, flamingos, vlei rats, hares and duiker (Cat Survival Trust 2002; Sunquist et al. 2002).

Feral cats in Australia also have a generalised diet that includes a variety of lizards, frogs, small birds, insects, fish, small mammals, domestic poultry and rabbits (Long 2003).

Servals achieve an extremely high rate of hunting success (49% of hunting attempts yield prey) (Geertsema 1985), compared with lions (30%) and most other cat species (10%) (Cat Survival Trust 2002).

Predators and diseases

Health issues specific to savannah cats are unknown due to the taxon's recent development (All About Spots 2007).

Some vets comment that savannah cats exhibit 'hybrid vigour' (heterosis) (Greig 2007).

Legal status of serval hybrids including savannah cats (overseas)

In the United States, there are restrictions on owning hybrid cats in some states. It is illegal to own hybrid cats in the state of Nebraska, since hybrid cats are not classified as the species *Felis domesticus* (Lyons 2008). In Massachusetts, savannah cats from the F1, F2, and F3 hybrid generations are not considered to be domestic cats under Massachusetts law (MGL:131, sec 77A), and it is illegal to possess such animals (Massachusetts Division of Fisheries and Wildlife 2007). In New York State, only hybrids removed from a wild felid parentage for a minimum of five generations are allowed as pets. The justification for the New York State law is that 'it is very difficult to track an animal's lineage; therefore making it difficult to determine what generation hybrid a cat may be' (New York State Assembly 2007). Hybrid cats are illegal under New York City law (New York City Administrative Code 2000), illegal in the state of Hawaii (State of Hawaii 2006), and in the state of Georgia (Georgia Department of Natural Resources 2007).

In the United Kingdom, the filial number of a particular hybrid cat determines if a permit is required for import: 'Certain hybrid animals may be subject to the provisions of the Convention on the International Trade in Endangered Species (CITES) and will require a CITES permit to enter the UK from third countries. A hybrid animal regulated under CITES is one that in its previous four generations has a parent the species of which is listed in Appendix I or II of CITES' (DEFRA 2006).

In Queensland, servals and their hybrids are invasive animals under the the Biosecurity Act 2014 and cannot be kept without a permit. Permits are not available for animals kept as pets.

Legal status of serval hybrids including savannah cats in Australia

The Australian government regulates the import of serval hybrids into Australia.

The serval is listed under Section 303EB(1) of the *Environment Protection and Biodiversity Conservation Act 1999* on the 'List of Specimens Taken to be Suitable for Live Import Part 2', which is the list of live specimens that require an import permit.

The serval is a CITES Appendix II listed species, so for the purposes of the *Environment Protection and Biodiversity Conservation Act 1999*, the definition of animal hybrids used by the CITES Conference of the Parties resolution 10.17 is used (as revised at the fourteenth meeting of the Conference of the Parties, The Hague (Netherlands), 3–15 June 2007). By this definition, a hybrid animal that has in its previous four generations of lineage one or more specimens included in Appendix I or II of the Convention shall be subject to the provisions of the Convention just as if they were the full species. Under this interpretation, F1 to F4 hybrids of *Leptailurus serval* (serval) and *Felis catus* (domestic cat) are treated as *Leptailurus serval* (serval). Servals can only be imported for an 'eligible non-commercial purpose only, excluding household pets'.

Domestic cats are listed under the *Environment Protection and Biodiversity Conservation Act 1999* Section 303 EB(1) as 'Specimens Taken to be Suitable for Live Import Part 1', which is the list of animals that do not require an import permit. However, this excludes any specimen of *Felis catus* derived from cross-breeding with: (a) a *Felis serval* or (b) a savannah cat (*Felis catus* × *Felis serval*).

The disease risk of imported animals is considered under the provisions of the *Quarantine Act*.

Potential distribution and impact in Queensland

It is difficult to accurately predict the potential geographic distribution of the savannah cat in Australia, simply because it is artificial hybrid that does not occur in the wild. However, it is reasonable to predict that its potential range is likely to be comparable to that of its progenitor species; the serval and the domestic cat.

Climate-based predictions have been generated for the wild serval (Figure 3) and the domestic (feral) cat (Figure 4), using CLIMATE, a climate modelling computer program. Based purely on an assessment of climatic parameters, large areas of Queensland appear suitable for both species, and hence their hybrids, especially the tropical savannahs of north Queensland. However, it is important to note that other habitat requirements, such as the availability of food, will influence range and abundance within this broad climatic envelope.

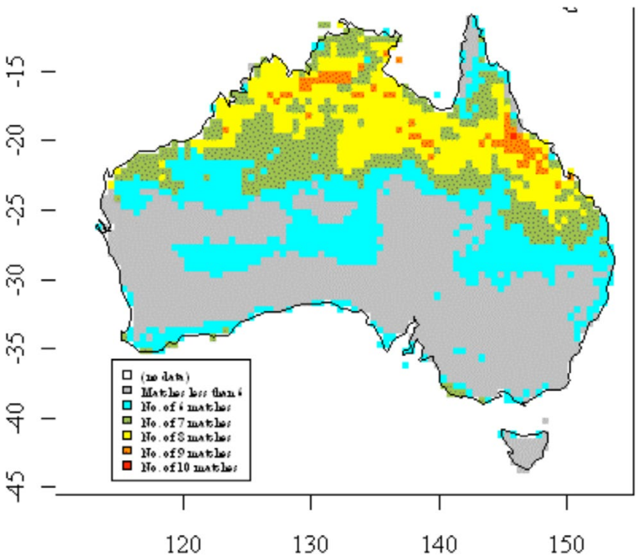

Figure 3. Potential distribution of the serval in Australia (red, orange and yellow indicates a high climatic suitability, green and light blue indicates marginal climatic suitability and grey indicates unsuitable climate).

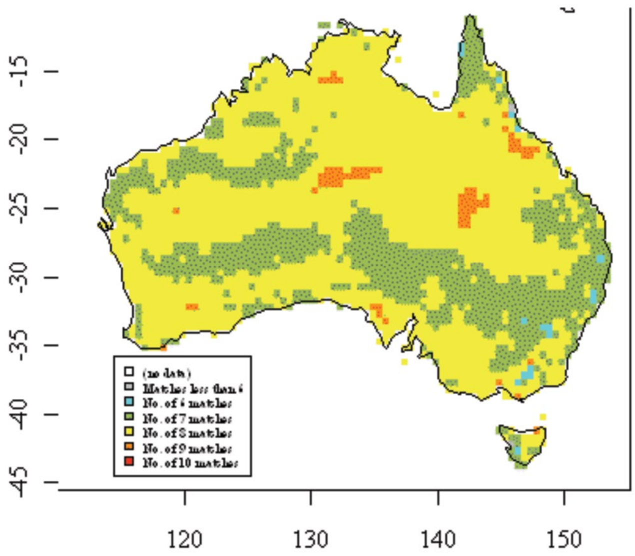

Figure 4. Potential distribution of the feral domestic cat (red, orange and yellow indicates a high climatic suitability, green and light blue indicates marginal climatic suitability and grey indicates unsuitable climate).

After reviewing the biological and ecological attributes of the serval and the feral domestic cat, this study suggests that the savannah cat is well suited to a broad range of habitat types, comparable to feral domestic cats. While it is difficult to predict exactly which habitats are most suitable, this study speculates that tropical savannahs are most suitable, followed by open grasslands in semi-arid areas and perhaps riparian habitats within the arid zone. The wild serval is known to have a broad habitat range, across tropical savannahs and extending to high altitude and adjacent arid zones in Africa. It is also commensal, occupying the margins of towns and settlements. Even though the savannah cat is not a pure serval, this taxon still exhibits many of the serval's wild traits, such as size, agility and behaviour.

While 90% of the wild serval's diet comprises prey items less than 200 g, it is known to take medium-sized mammals, birds and reptiles. Hence, it is reasonable to predict that Australian small and medium-sized vertebrate fauna are at risk, and that there do not appear to be any dietary limitations to the hybrid's survival in the wild.

Perhaps of most concern is the potential for genetic material from the savannah cat hybrid (and from the wild serval) to enter the existing feral cat population in Australia. Given the size and agility of the wild serval and the savannah cat, it seems reasonable to expect that cross-breeding with feral domestic cats could result in considerably larger feral cats. Also, considering the high kill-rate of the wild serval (50%), in comparison to feral cats (10%), any cross-breeding could result in increased hunting efficiency within the feral cat population.

Australian small to medium sized mammals have already suffered a high extinction rate, due largely to introduced predators. There is a good chance that the savannah cat will exacerbate this problem. Since European settlement, eighteen species of mammals have become extinct in Australia and a further nine have disappeared from the mainland and persist only on islands. Many other mammal species have declined to remnant mainland populations. These declines are strongly biased towards the arid and semi-arid zones and towards species within a critical weight range (35 g – 5.5 kg, Burbidge and McKenzie 1989). Ground-dwelling species in open habitats were particularly vulnerable. While there has been debate about the cause (e.g. Morton 1990), predation by feral cats and foxes has always been considered a factor. It is also well recognised that reintroduction of endangered, ground-dwelling mammal species in Australia is likely to fail unless cat and fox predation can be controlled (Serena 1994, Sinclair et al. 1998). A recent assessment of the likely causes of mammal decline in Australia strongly argues that predation by foxes and cats is largely responsible (Johnson 2006).

The declines in Australia's mammal fauna have also been concentrated in the southern two-thirds of the continent, coinciding with the distribution of foxes (Morton 1990). There are numerous species of mammals within the critical weight range that occur in northern Australia and some have experienced marked declines in southern Australia (Strahan 1995). The potential distribution of the serval overlaps the range of many of these species and includes Australia's extensive tropical savannah woodlands, a habitat preferred by the serval. Savannah cats are approximately twice the weight of feral cats in Australia and so have the potential to take prey similar to the size taken by foxes in southern Australia.

It is important to note that these predictions are speculative and based more or less on what we know about the wild serval (refer to separate risk assessment on the serval). This study was unable to find any published information on impacts of savannah cats since they are a new breed.

Numerical risk assessment using the Bomford assessment

A numerical risk assessment system developed by Bomford (2006) is widely applied in Australia to assess the level of risk posed by particular vertebrate species. This approach enables numerical ranking and prioritisation of large numbers of species. Firstly, a species' potential distribution is predicted using climate-modelling computer programs. The remaining steps involve allocation of scores for a number of attributes relevant to a species' pest status, including biology, costs to the economy, the environment and society, and management efficacy.

Using the Bomford system, serval/domestic cat hybrids were assessed as an 'extreme' threat to Queensland (refer Appendix 1).

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Appendix

Risk assessment

Using the Bomford (2006) system, hybrids of *Leptailurus serval* (serval) and *Felis catus* (domestic cat) in Queensland were considered an 'Extreme' threat.

Species:	Hybrids of *Leptailurus serval* (serval) and *Felis catus* (domestic cat)	
Date of assessment:	26 June 2008	
Literature search type and date:	See references	
A. Risks to public safety		
Factor	**Score**	**Comments**
A1. Risk to people from individual escapees (0–2)	1	Servals that are kept as pets have attacked unprovoked, causing serious injuries that require hospitalisation. Feral domestic cats can attack causing injury if cornered and threatened.
A2. Risk to public safety from individual captive animals (0–2)	1	Physical safety: apart from someone entering an enclosure or otherwise being in reach of a captive animal, there is nil or low physical risk to public safety. Disease transmission. Zoonotic diseases known to pass from cats to humans include: cat-scratch disease (bartonellosis), by far the most common zoonotic disease associated with cats, with approximately 25 000 people diagnosed every year in the United States; Salmonellosis, fungal infections (e.g. ringworm; protozoal infections such as toxoplasmosis caused by *Toxolasma gondii*). People with weakened immune systems, or infants whose mothers are infected during pregnancy, can develop severe illness. Risk of disease transmission to humans should be no more than from existing pet domestic cats.
Stage A. Public safety risk score = sum of A 1 to 2 (0–4).	**2**	**Highly dangerous**
B. Risk of establishing a wild population		
Factor	**Score**	**Comments**
B1. Degree of climate match between species overseas range and Australia (1–6)	6	Both the serval and domestic cat have extreme climate match to Australia. The hybrid is not expected to be any more limited by climate than its progenitors.
B2. Exotic population established overseas (0–4)	4	Servals only exist in wild populations in Africa and are kept as pets in the United States and Europe. There is no record of servals establishing outside of Africa. Feral populations of domestic cats are common throughout the world.
B3. Taxonomic Class (0–1)	1	Mammal
B4. Non-migratory behaviour (0–1)	1	The serval is non-migratory in its native range. **The feral domestic cat** is also non-migratory.

B. Risk of establishing a wild population (cont.)		
Factor	**Score**	**Comments**
B5. Diet (0–1)	1	The serval has a generalist diet that includes a variety of prey species: lizards, snakes, frogs, small birds (quails, quelea, teal), insects, fish, ground squirrels, hyraxes, mole rats, domestic poultry, small antelopes, flamingos, vlei rats, hares and duiker. The feral domestic cat in Australia has a generalised diet that includes a variety of lizards, frogs, small birds, insects, fish, small mammals, domestic poultry and rabbits. The hybrid would be expected to utilise at least the same range of prey.
B6. Lives in disturbed habitat (0–1)	1	Servals and domestic cats adapt very well to human agricultural environments. Domestic cats live in a wide range of disturbed habitats including urban.
B7. Overseas range size (0–2)	2	Introduced range of domestic cats is quite large covering several continents. Servals are now restricted to sub-Saharan north, central and southern Africa.
B. Establishment Risk Score = Sum of B1 to B7 (1–16).	**16**	**Extreme**
C. Risk of becoming a pest following establishment		
Factor	**Score**	**Comments**
C1. Taxonomic group (0–4)	2	Carnivora
C2. Overseas range size including current and past 300 years, natural and introduced range (0–2)	2	Serval: 12.5 million km^2 (based on distribution in Nowell and Jackson, 1996). Domestic cat: >30 million km^2
C3. Diet and feeding (0–3)	3	The serval, domestic cat and hybrid are all strict carnivores and arboreal.
C4. Competition with native fauna for tree hollows (0–2)	2	The serval can use hollow trees to shelter young.
C5. Overseas environmental pest status (0–3)	3	The serval is not an environmental pest in any country or region. The feral domestic cat is a severe environmental pest in many countries, especially islands.
C6. Climate match to areas with susceptible native species or communities (0–5)	5	The species has more than 20 × 10% climate match (closest match) grid squares, and/or more than 100 grid squares within a 30% climate match, that overlap the distribution of any susceptible native species or communities. Of those species on the EPBC Act threatened species list, feral cats are considered a threat to 37 mammals, 36 species of birds (with 5 of these—the Christmas Island pipistrelle, orange bellied parrot, spotted quail-thrush (Mt Lofty Ranges), herald petrel and Gilbert's potoroo—being critically endangered), 7 reptiles and 3 amphibians.
C7. Overseas primary production pest status (0–3)	2	Moderate pest of primary production in any country or region—will take domestic poultry.

C. Risk of becoming a pest following establishment (cont.)		
Factor	**Score**	**Comments**
C8. Climate match to susceptible primary production (0–5)	3	Commodity damage score = 85
C9. Spread disease (1–2)	2	All birds and mammals (likely or unknown effect on native species and on livestock and other domestic animals)
C10. Harm to property (0–3)	0	$0
C11. Harm to people (0–5)	3	Injuries or risk of harm moderate; unlikely to be fatal and few people at risk (see A1). Human exposure to zoonotic disease not likely to be greater than that posed by current domestic cat.
C. Pest Risk Score = sum of C1 to C11 (1–37).	**27**	**Extreme**
Summary		
Stage A. Risk to public safety posed by captive or released individuals. (Public safety risk score = 0—not dangerous; 1—moderately dangerous; ≥2—highly dangerous)	2	**Highly dangerous**
Stage B. Risk of establishing a wild population. (For birds and mammals: Establishment Risk Score ≤6—low establishment risk; 7–11—moderate establishment risk; 12–13—high establishment risk; ≥14—extreme establishment risk).	16	Extreme establishment risk
Stage C. Risk of becoming a pest following establishment. (Pest risk score: <9—low pest risk; 9–14—moderate pest risk; 15–19—high pest risk; >19—extreme pest risk).	27	Extreme pest risk
VPC threat category	**Extreme**	

Table 3 Calculating Total Commodity Damage Score

Industry	Commodity Value Index[1]	Potential Commodity Impact Score (0–3)	Climate Match to Commodity Score (0–5)	Commodity Damage Score (columns 2 × 3 × 4)
Sheep (includes wool and sheep meat)	10	1	5	50
Cattle (includes dairy and beef)	10	0	Not estimated	0
Timber (includes native and plantation forests)	10	0	Not estimated	0
Cereal grain (includes wheat, barley sorghum etc)	10	0	Not estimated	0
Pigs	2	0	Not estimated	0
Poultry and eggs	2	2	5	20
Aquaculture (includes coastal mariculture)	2	1	5	10
Cotton	2	0	Not estimated	0
Oilseeds (includes canola, sunflower etc)	2	0	Not estimated	0
Grain legumes (includes soybeans)	2	0	Not estimated	0
Sugarcane	2	0	Not estimated	0
Grapes	2	0	Not estimated	0
Other fruit	2	0	Not estimated	0
Vegetables	2	0	Not estimated	0
Nuts	1	0	Not estimated	0
Other livestock (includes goats, deer, camels, rabbits)	1	1	5	5
Honey and beeswax	1	0	Not estimated	0
Other horticulture (includes flowers etc)	1	0	Not estimated	0
Total Commodity Damage Score (TCDS)	—	—	—	85