RISK ASSESSMENT FOR AUSTRALIA – Domestic Sheep (*Ovis aries*) (Linnaeus, 1758)

Class - Mammalia, Order - Artiodactyla, Family - Bovidae (Gray, 1821), Genus - *Ovis* (Linnaeus, 1758); (Wilson and Reeder 1993, ITIS Integrated Taxonomic Information System 2007, Catalogue of Life 2008)

GOVERNMENT OF WESTERN AUSTRALIA

Department of Agriculture and Food

Score Sheet

SPECIES: Domestic Sheep (*Ovis aries*) (Gentry et al 2004)		This risk assessment for *Ovis aries* includes information at a breed-specific level for the Merino, Damara, and Dorper sheep breeds. When available, this information was included in some Stage B questions to investigate the possibility of giving a separate establishment risk score for a particular breed. Although the breeds display some dissimilar physical and behavioural attributes these were not significant enough to separate the pest risk (Stage C) for the breeds. The available distribution data was used differently for six climate analysis (fully described below and distribution maps 1 to 6). The climate analyses include: 1. A typical climate analysis uses the overseas natural and introduced distribution of a species, excluding any populations in Australia. However, in the case of Domestic Sheep (*O. aries)*, no natural populations have existed in the wild for more than 1000 years therefore, the range of introduced or feral populations of DOMESTIC Sheep (Wilson and Reeder 1993) have been used (distribution Map 1 & climate analysis 1). 2. As no natural distribution of the species occurs, an analysis using the historical range of the Domestic Sheep's wild ancestor, the Asiatic Mouflon (*O. orientalis*) (Hiendleder et al 1998) (Wilson and Reeder 1993) (distribution Map 2 & climate analysis 2) has been done for COMPARISON. 3. Merino analysis (distribution Map 3 & climate analysis 3). Introduced populations of sheep documented in the literature as being of the Merino breed are used for the Merino analysis. 4. Damara Sheep Breed analysis (distribution Map 4 & climate analysis 4). No available breed-specific information in the literature regarding introduced populations of Damara. Therefore, areas where the breed was developed in South Africa have been used as a substitute. This method is not typical and its use was justified by the untested reasoning that the Damara BREED WAS DEVELOPED for the climatic conditions particular to that area of South Africa. 5. Dorper Sheep Breed analysis (distribution Map 5 & climate analysis 5). Again, no breed-specific information was available, therefore, the same untested method of using the PARTICULAR area of South Africa where the Dorper breed was developed has been used. 6. For interest in predicting other areas of Australia where Domestic Sheep may HAVE POTENTIAL TO establish feral populations, climate analysis 1 was repeated with the addition of known feral populations already established in Australia (distribution Map 6 & climate analysis 6). This analysis has not been included in any of the assessment scores. **Species Description** – Head and body length 1200-1800 mm, tail length 70-150 mm, shoulder height 650-1270 mm, and weight 20-200 kg. There is much variation in size among different breeds of domestic sheep. In any given population males (rams) average larger sizes than females (ewes). Colouration varies from creamy white to dark grey and brown. Most feral sheep resemble domestic sheep in appearance and size. The coat is a crimped, woolly fleece with occasional hair fibres. It may be short and neat or long and untidy, depending on the population and the stage of the moult cycle. Self-shedding of the fleece is common in some breeds. No wild sheep species has a woolly coat comparable to that of *O. aries*. When the domestic sheep becomes feral, it gradually loses much of its woolly pelage and develops a coat of coarse hairs,

similar to the kind found in the wild species. The nose is narrow and completely covered with short hair except on the margins of the nostrils and lips; the ears are pointed. Either sex may carry horns (or 'scurs'), which are small horny pads or cones, not attached to the skull, not visible above the fleece, and which never develop into true horns. Horns have alternative grooves and ridges. In females they are slender, more or less erect and curved backwards; in males they are more massive, with broad anterior surfaces, and after curving back they spiral outwards for up to two turns. Wild animals have tails between 70-150 mm in length, but in domestic sheep tails may be larger and used as a fat reserve, although these long tails are removed on most commercial farms (Nowak 1999, Long 2003, King 2005, Global Invasive Species Database 2006).

The Merino Sheep Breed produces heavy fleece and fine wool. Of the approximately 100 million sheep in Australia, over 80 % are pure Merino (Australian Wool Innovation 2008). The Merino is valued for its fine wool. It is a medium-sized sheep, and has a highly developed flocking instinct. Most Merino rams have curved horns, although a hornless, or "polled", variety has been developed (The American Delaine & Merino Record Association 2008). Another well-known feature of the Merino is the copious folds of skin around its neck (Adams and McKinley 1995).

The Damara Sheep Breed is said to have originated in ancient Southern Angola and Northern Namibia (Griffith 1998). It is a fairly large sheep in terms of shoulder height. The ewes appear more delicate the rams that appear more robust. The breed also has long legs and a fat-storing tail. It is predominantly a horned sheep; the rams have well developed spiral horns which stand well away from the head. The Damara has a wide range of colours. Hair is mostly short with a tendency to have a fine layer of wooliness developing under the hair during winter. Rams often have long hair along the throat down to the brisket. This breed has a fairly high resistance to most sheep diseases and also good tolerance against internal parasites (Higham 2002, Department of Animal Science 2007, Schoenian 2007, Damara Sheep Breeders Society of Australia 2008).

The Dorper Sheep Breed is a South African breed developed during the 1930s by crossing a Blackhead Persian ewe with a Dorset Horn ram. The Dorper is hornless with a good body length and a short, light covering of hair and wool, which will drop off if not shorn. The breed has a characteristic black head and white body (Dorper), as well as a white head (White Dorper). The Dorper is one of the most fertile of sheep breeds (Brand 2000, Farm Diversification Information Service and Castleman 2000, Milne 2000, Higham 2002, Department of Animal Science 2007, Schoenian 2007, DSSA 2008).

General information – Nearly 1,200 breeds of domestic sheep have been developed, of which 148 are believed to have become extinct within the last 100 years. Intensive breeding for particular purposes has resulted in many varieties (Adams and McKinley 1995, Nowak 1999).

Longevity – Longevity depends on population status. In a declining or stable population with low recruitment most sheep live more than 10 years, with a maximum of 20 years for rams and 20-24 years for ewes. In an expanding population with heavy reproduction the average life span is only 6-7 years (Nowak 1999, HAGR Human Ageing Genomic Resources 2006).

Status – There are currently more than 1 billion domestic sheep in the world (Nowak 1999).

Red List Category – Not listed (IUCN 2008).

CITES listed Protection Status – Not listed (CITES 2007).

DATE OF ASSESSMENT: 28/05/2008

Bird and Mammal Model used (Bomford 2008) using PC CLIMATE (Brown et al 2006, Bureau of Rural Sciences 2006)

The Risk Assessment Model

Models for assessing the risk that exotic vertebrates could establish in Australia have been developed for mammals, birds (Bomford 2003, Bomford 2006, 2008), reptiles and amphibians (Bomford et al 2005, Bomford 2006, 2008). Developed by Dr Mary Bomford of the Bureau of Rural Sciences (BRS), the model uses criteria that have been demonstrated to have significant correlation between a risk factor and the

		establishment of populations of exotic species and the pest potential of those species that do establish. For example, a risk factor for establishment is similarity in climate (temperature and rainfall) within the species' distribution overseas and Australia. For pest potential, the species' overseas pest status is a risk factor. The model was originally published in 'Risk Assessment for the Import and Keeping of Exotic Vertebrates in Australia' (Bomford 2003) available online http://www.daff.gov.au/brs/land/feral-animals/management/risk . This model used the Apple Mac application CLIMATE (Pheloung 1996) for climate matching. The risk assessment model was revised and recalibrated 'Risk Assessment for the Establishment of Exotic Vertebrates in Australia: Recalibrated and Refinement of Models'(Bomford 2006) and the climate application changed to PC CLIMATE software (Bureau of Rural Sciences 2006), available online at http://affashop.gov.au/product.asp?prodid=13506. The most recent publication (Bomford 2008) includes updated instructions for using the exotic vertebrate risk assessment models and an additional model for freshwater fish. A bird and mammal model for New Zealand has also been included. **Which models are being used for the assessments:** Birds and mammals have been assessed using the Australian Bird and Mammal Model (Bomford 2008), pp 16-28, including both versions of stage B, models 1 (4 factors) and 2 (7 factors). All reptiles and amphibians were assessed using three models; the Australian Bird and Mammal Model (Bomford 2008), including Model A, using 3 factors from stage B (pp 54-55), and Model B, using 7 factors from stage B (pp 20), and the Australian Reptile and Amphibian Model (Bomford 2008), p 51-53. The rational for using additional models for reptiles and amphibians is to compare establishment risk ranks of the three models for a precautionary approach. If the models produce different outcomes for the establishment potential of any reptile or amphibian, the highest ranked outcome should be used (Bomford 2008). **Climate Matching Using PC CLIMATE** Sixteen climate parameters (variables) of temperature and rainfall are used to estimate the extent of similarity between data from meteorological stations located in the species' world distribution and in Australia. Worldwide, data (source; worlddata_all.txt CLIMATE database) from approximately 8000 locations are available for analysis. The number of locations used in an analysis will vary according to the size of the species' distribution. Data from approximately 762 Australian locations is used for analysis. To represent the climate match visually, the map of Australia has been divided into 2875 grid squares, each measured in 0.5 degrees in both longitude and latitude. CLIMATE calculates a match for each Australian grid by comparing it with all of the meteorological stations within the species' distribution (excluding any populations in Australia) and allocating a score ranging from ten for the highest level match to zero for the poorest match. These levels of climate match are used in the risk assessment for questions B1 (scores are summed to give a cumulative score), C6, and C8. For a grid square on the Australian map to score highly, it must match closely all 16 climatic variables of at least one meteorological station in the species' distribution, for each level of climate match. [The score for each grid is based on the minimum Euclidian distance in the 16-dimensional variable space between it and all stations in the species' distribution. Each variable is normalized by dividing it by its worldwide standard deviation.]
LITERATURE SEARCH TYPE AND DATE: NCBI, CAB Direct, MEDLINE, Science Direct, Web of Knowledge (Zoological Records, Biological Abstracts), SCIRUS, Google Search and Google Scholar 24/04/2008		
FACTOR	**SCORE**	
STAGE A: RISKS POSED BY CAPTIVE OR RELEASED INDIVIDUALS		

A1. Risk to people from individual escapees (0–2) *Assess the risk that individuals of the species could harm people. (NB, this question only relates to aggressive behaviour shown by escaped or released individual animals. Question C11 addresses the risk of harm from aggressive behaviour if the species establishes a wild population).* *Aggressive behaviour, size, plus the possession of organs capable of inflicting harm, such as sharp teeth, claws, spines, a sharp bill, or toxin-delivering apparatus may enable individual animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account. Assume the individual is not protecting nest or young. Choose one:*	1	*Animal that can make unprovoked attacks causing moderate injury (requiring medical attention) or severe discomfort but is highly unlikely (few if any records) to cause serious injury (requiring hospitalisation) if unprovoked* Head butting is both a natural and learned behaviour in sheep. Head butting amongst rams is used to establish dominance, and the behaviour occurs most during the rutting season. No matter how friendly a ram is, he should never be trusted, and a person should never turn their back to a ram. Rams can cause serious injury to people and other animals (Schoenian 2007). A man was knocked to the floor when he attempted to chase a sheep from his garden. The animal dodged past him and into the house. The sheep then ran and head butted the man, who suffered two broken bones in his leg (BBC News 2006). An elderly couple were killed as they fed and watered their flock of sheep, when a ram weighing over 100 kg attacked. Investigators and relatives say the ram might have been trying to protect ewes during mating season (Animal Attack Files 2000).
A2. Risk to public safety from individual captive animals (0–2) *Assess the risk that irresponsible use of products obtained from captive individuals of the species (such as toxins) pose a public safety risk (excluding the safety of anyone entering the animals' cage/enclosure or otherwise coming within reach of the captive animals)*	0	*Nil or low risk (highly unlikely or not possible)*.
STAGE A. PUBLIC SAFETY RISK SCORE **SUM A1 TO A2 (0–4)**	**1**	

STAGE B: PROBABILITY ESCAPED OR RELEASED INDIVIDUALS WILL ESTABLISH FREE-LIVING POPULATION

Model 1: Four-factor model for birds and mammals (BOMFORD 2008)

B1/1. Degree of climate match between ***Domestic Sheep's (no breeds distinguished) introduced overseas distribution*** *and Australia (1–6)*	2	*1. Climate Match Score = 277 Low match with Australia* using the overseas distribution of introduced domestic sheep (see B2.), excluding populations in Australia. The species' natural distribution is usually included in the climate analysis, however in the case of *O. aries*, there are no natural populations in the wild. Therefore, the distribution of introduced populations worldwide, excluding those in Australia, have been used in accordance with (Bomford 2008) Climate data from 154 locations (see distribution, Map 1) were used to calculate the CMS; no natural distribution, but introduced populations occur worldwide (Long 2003) (see B2 and B7 for details). [See above information on climate matching.]
B1/2. Degree of climate match between, the ***Domestic Sheep's ancestor's (the Mouflon) natural distribution*** *and Australia (1–6)*	2	*2. Climate Match Score= 497 Low match with Australia* using the historical distribution of the domestic sheep's ancestor, the Mouflon (distribution Map 2). An alternate method of climate matching for species which have no naturally occurring populations is to use the distribution of the species' wild ancestor (Bomford 2008), which for *O. aries* is the Asiatic Mouflon (*O. orientalis*) . This alternate climate analysis has been included for comparison with the introduced population analysis. Climate data from 244 locations were used to calculate the CMS.
B1/3. Degree of climate match between ***Merino Sheep breed's introduced overseas distribution*** *and Australia (1–6)*	2	*3. Climate Match Score = 126 Low high match with Australia* using the overseas distribution of introduced Merino Sheep (Map 3). This merino-breed analysis has been included to distinguish different levels of establishment risk for three sheep breeds. Climate data from 114 locations were used to calculate the CMS.

B1/4. Degree of climate match between ***overseas distribution where Damara Sheep breed was developed*** *and Australia (1–6)*	2	*4. Climate Match Score = 493 Low climate match with Australia* using the Damara Sheep's South African distribution in Namibia and Angola, where the breed was developed (distribution Map 4). No information was available for introduced populations of Damara, therefore, the area in South Africa where the breed was developed was used for an alternate typical analysis. The Damara-breed analysis has been included to distinguish different levels of establishment risk for three sheep breeds. Climate data from 16 locations were used to calculate the CMS.
B1/5. Degree of climate match between ***overseas distribution where Dorper Sheep breed was developed*** *and Australia (1–6)*	4	*5. Climate Match Score = 1610 High climate match with Australia* using the Dorper Sheep's southern South African distribution, where the breed was developed (distribution Map 5). No information was available for introduced populations of Dorper, therefore, the area in South Africa where the breed was developed was used for an alternate atypical analysis. The Dorper-breed analysis has been included to distinguish different levels of establishment risk for three sheep breeds. Climate data from 72 locations were used to calculate the CMS.
B2/1. Exotic population established overseas of ***Domestic Sheep (no breeds distinguished)*** *(0–4)*	4	*Exotic population established on an island larger than 50 000 km^2 or anywhere on a continent* Feral populations of domestic sheep have become established in many parts of the world, notably islands (Nowak 1999). Where known, the breed of sheep has been included in the following information. [Note: CLIMATE data is not available for many of the smaller islands to which sheep have been introduced; therefore, for some of the following introductions the island can not be displayed on the distribution map.] **Europe** ▪ Norway and Sweden – A semi-feral population of sheep existed in southwest Norway where they were protected from hunting, but their presence has not been confirmed recently. A flock of 100 ewes and six rams of a Swedish breed live on Lilla Karlso off Gotland in the Baltic Sea (Rudge 1984, Lever 1985, Long 2003). ▪ United Kingdom – In 1934, 8 Soay sheep (a small European sheep, see information below) were sent to Skokholm Island (in the Irish Sea off the Pembrokeshire coast) where in 1944 there were 40. Up to 76 existed there until 1959-60. In 1968 only one was seen (Rudge 1984, Long 2003). – 4 Soay sheep were sent to Cardigan Island, Cardigan Bay, in 1944, and by 1959 the flock numbered 70 animals (Long 2003). – In 1932, 4 Soay sheep were sent to St. Margaret's Island (near Tenby) which increased to 20-30 by 1959, but all were killed by lightning late in the same year (Long 2003). – Some Soay sheep were introduced to the island of Skomer in 1958 and two years later there were 40 sheep on Skomer, Skokholm and Cardigan Islands (Long 2003). – At one time, Soay sheep were also kept at Middleholm between Skomer and the mainland (Long 2003). – Soay sheep were introduced to Lundy Island in 1927, and these increased to 80 by 1959. Some were still present in 1973 (Rudge 1984, Long 2003). – Soay sheep were introduced to Ailsa Craig Island in the 1930s, and in 1956 there were still 14 there (Rudge 1984, Long 2003). – Feral Soay sheep occur on St Kilda island, though it is thought that they may have been introduced

in prehistoric times, or by Vikings around 800 AD (Rudge 1984, Lever 2001, Long 2003).

- There are semi-feral sheep on North Ronaldsay Island, in the Orkney Islands. They have been there possibly since the Neolithic Period (Rudge 1984, Long 2003).

[Note: The Soay (*Ovis aries* L.) is a small European sheep. It is often grouped with the Northern Short-tail but is in fact more primitive (Ryder, 1983). It may even be more accurate to describe it as a prehistoric sheep rather than an individual breed. No one is certain of its origins, but some believe it could be a living remnant of a semi-domestic sheep brought to Britain prior to the invasion of the Romans. The Soay is accepted as being one of the UK's oldest surviving livestock breeds. Because of its widely diverse genetics and its complete isolation on the tiny, uninhabited St. Kilda island of Soay, west of Scotland, this feral ungulate evolved into an adaptable animal capable of surviving in a challenging environment. Since the late nineteenth century conservationists, farmers and handspinners in Scotland and England have kept Soay in small numbers and a few are now found in Europe as well as the United States (Miller 2008).]

Pacific Ocean Islands

- Galapagos Islands (Ecuador) – Sheep were introduced to Isabela Island in the 19th century, but it is not known if they were feral sheep or whether they are now extinct (Rudge 1984, Long 2003).
- Hawaiian Islands (US)
  - Sheep were introduced to Kauai in 1791, and more introductions followed in 1793 and 1794. Sheep occur on all the islands except Oahu (Rudge 1984, Lever 1985, Long 2003).
  - Introduced to Mauna Kea in 1793-94, sheep became well established 1822, and have been there ever since. Lacking natural predators except for wild dogs, the sheep population reached about 40,000 animals by the early 1930s. A stock-proof fence was built around the Mauna Kea Forest Reserve and the sheep population was reduced through sheep drives and hunter-guide programs. Fewer than 500 feral sheep remained by 1950. Control efforts were then relaxed, and populations subsequently increased. There were about 2000 present in 1976, probably **Merino**, but also some cross-breeds (Rudge 1984, Lever 1985, Scowcroft and Conrad 1992, Long 2003, King 2005).
  - Sheep were introduced to Kahoolawe Island in the 18th century. About 2000 sheep remained on the island in 1859 following the failure of farming; 300-400 sheep now remain (Rudge 1984, Lever 1985, Long 2003).
- Juan Fernandez Island (Chile) – Sheep are present, but it is not known if they are feral (Rudge 1984, Lever 1985, Long 2003).
- Kerguelen (France) – Sheep were introduced to Kerguelen in 1909. Some were imported to Ile Longue, and in 1911, 1000 were liberated on Presque'Ile Bouquet de la Grye. Those sheep on the islands were largely maintained by shepherds, but this venture was interrupted between 1914 and 1921, but recommenced at Port Couvreaux and Ile du Corbeau until finally abandoned in 1932. Some sheep were also landed on Ile Mussel in 1952. Some sheep escaped to Grande Terre while they were being moved before slaughter, and in 1973 about 70 were living wild there. The sheep were a **mixed race**, dominant type 'Bizet' (Rudge 1984, Long 2003).
- Macquarie Island (Australia) – Sheep were introduced in 1947 and a flock of 15 was kept on the island, but they did not become established as a feral species (Long 2003).
- New Zealand – Sheep, mainly **Merino** or **Merino-cross** have been feral at times in New Zealand since the early 19th century, starting with 5 **Australian Merinos** imported in 1814. Feral populations were widespread during the 19th century, and have remained feral in some remote areas of both the North and South islands. While formerly widespread on the main islands, only eight discrete flocks remain on

the mainland in remote areas, and four flocks remain on Arapanua, Chatham, Pitt and Campbell Islands. Domestic Sheep occasionally reach places where they cannot be mustered, but generally they are all ewes or wethers and so cannot establish new feral populations (Parkes 2001, Long 2003, Parkes and Murphy 2003, King 2005).

- Domestic Sheep were introduced to Campbell Island in 1895, 1901 and 1902 and were managed for their wool until 1931 when management was discontinued. The sheep population peaked at 8500 in 1910. When abandoned as a farming venture, some 4000 sheep where left to run wild. Since 1941 shooting reduced their numbers by about 50 sheep per year, but the herd was also naturally declining at a rate of 5 % annually from 1916 up until 1961. About 950-1000 were present in 1961. However, by 1969 the population had increased to 3000. The island was fenced across the middle in 1970, and 1300 sheep on the northern half were killed. The sheep continued to increase in numbers on the southern half of the island and by 1977 numbered 2861 (Dilks and Wilson 1979, Rudge 1986, Long 2003, King 2005).
- A flock of 300 sheep, thought to be of **Merino** origin, exist in a feral state in a 2 km^2 reserve created on Pitt Island, Chatham Islands, New Zealand. They were first reported there in 1900,. These feral sheep are regarded as an asset by hunters and fishermen from Pitt and Chatham islands as the meat is appreciated for being sweet, lean, and free for the taking (Rudge 1983, Rudge 1984, Long 2003, King 2005).
- Sheep were present on the Antipodes islands in 1887, but died out at a later date (Rudge 1984, Long 2003).
- Sheep were introduced a number of times on Auckland Island in the 1840s and 1850s, and again in the 1890s and early 1900s, but failed to become permanently established (Long 2003).
- Sheep were released on Adams Island in the 1880s and 1890s, but did not survive for more than a few years (Lever 1985, Long 2003).
- Sheep were introduced to Enderby Island in about 1850, and again in the 1890s, but disappeared after a few years, and also to Rose Island in the 1890s (Rudge 1984, Long 2003).
- **Domestic** Sheep were introduced to Mangere Island before 1900 or during the early 1900s, and became feral when they were abandoned at a later date. In 1968, all sheep had been removed from the island (Lever 1985, Long 2003).
- **Merino** Sheep were introduced to Arapawa Island before the 1880s (Long 2003).

▪ San Clemente Island (Channel Islands, US) – Early reports list sheep on the island. They were probably introduced there before 1862 however, they no longer occur (Long 2003).

▪ Santa Cruz Island (California Channel) – sheep ranching began in 1850s. By 1857, there were 7000-8000 sheep, and by 1890 there were about 50,000 on the island. By the 1920s many had become feral, they could not be captured and attempts to control them were abandoned. Many were shot and trapped but despite these efforts many thousands remained in a feral state. The sheep were mainly **Merino** with some Rambouillet and Leicester inbred. Between 1979 and 1981 there were about 21,240 sheep on the island. Sheep were introduced to other California Channel Islands, including San Miguel, Santa Rosa, Anacapa, Santa Barbara, San Nicolas, and Santa Catalina, but have since been extirpated (Brumbaugh et al 1982, Rudge 1984, Lever 1985, McChesney and Tershy 1998, Long 2003).

▪ Society Islands (part of French Polynesia) – Captain Cook gave sheep to the natives on Otaheite in the Society Islands, but the sheep did not survive (Rudge 1984, Lever 1985, Long 2003).

▪ Socorro Island (off Mexico) – **Merino** sheep were brought to the island beginning in 1869, and possibly

		continued through the 1880s. The population was around 2000 animals in 1988. Nothing is known of their abundance during intervening years except that they were present in good numbers. Today they survive and prosper as a feral population (Walter and Levin 2008). **Indian Ocean Islands** ▪ New Amsterdam (France) – a small flock of sheep existed on the island in 1957 (Rudge 1984, Long 2003). ▪ St Paul (France) – sheep were imported to the island some time before 1961, numbers are sparse (Long 2003). ▪ South Georgia (off South America) – sheep may have been present once, but are no longer (Long 2003). ▪ Tristan da Cunha (St. Helena) (2,816 km from the south-west coast of South Africa) – sheep were introduced to the island in 1824 and were present In 1829. In 1938 there were seven on Inaccessible Island. During the 1940s and 1950s, sheep were grazed on Tristan under partial confinement. The island was vacated in 1961 when a volcano erupted, 740 sheep were left unattended, but on the return of people to the island in 1963 most of the sheep had been killed by dogs also left on the island (Long 2003). ▪ Marion and Prince Edward Islands (South Africa) – sheep were imported in 1927, but failed to establish (Long 2003). ▪ Gough Island (a remote island, 2,700 km from Cape Town, South Africa) – sheep were introduced to the island in 1956, but are confined in enclosures (Rudge 1984, Lever 1985, Long 2003). **North America** ▪ Canada – sheep are run on some of the larger islands off British Colombia, and sometimes are feral. Sheep were introduced in the 19th century, and occurred on Lasqueti Island, Saltspring Island, Chatham Island, DeCourcey Island, and Saturna Island (British Colombia) in the 1980s (Rudge 1984, Long 2003). ▪ United States (mainland) – Small feral flocks, of less than a dozen or so sheep, may still exist in the Split Mountain Gorge in north-eastern Utah; Southern Ute Indian Reservation in south-west Colorado; Jefferson County in Oregon; and Morgan County in northern Alabama. Little is known of their origin (Rudge 1984, Lever 2001, Long 2003) – Experimental breed of sheep (Mouflon x Rambouillet) are still present in numbers in Texas (no information on whether these are feral or on farms/ranches) (Rudge 1984, Long 2003). **West Indies** ▪ Hispaniola – feral sheep were reported at Anse-a-Pitres in 1797-98, but none were present in Haiti in the early 1950s (Long 2003). ▪ Puerto Rico – feral sheep were present on Salt Island, but have since disappeared as no vegetation remains on the island (Long 2003). **Other islands** ▪ Sao Tome and Principe – located in the Gulf of Guinea in the Atlantic Ocean. Feral sheep are present, probably arriving with the first settlers in the late 1400s. Introductions continued as agricultural expansion and settlement increased but it is not known when sheep become feral (Dutton 1994).

		Australia ▪ <u>Australian mainland</u> – Few flocks of feral sheep have ever become established for any length of time. Some occasionally escape into the wild from sheep stations, but few exist for long. In the late 1920s over 300 sheep, thought to be **Merino**, were released in the Kimberley area of Western Australia, where their descendants survived in a small remnant flock some 40 years later. Today in Australia, feral sheep are almost unknown (Rudge 1984, Lever 1985, Long 2003).
B2/2. Exotic population established overseas of the ***Domestic Sheep's ancestor (the Mouflon)*** *(0–4)*	0	*No exotic population ever established* No reports found (Nowak 1999, Long 2003).
B2/3. Exotic population established overseas of the ***Merino Sheep breed*** *(0–4)*	4	*Exotic population established on an island larger than 50 000 km^2 or anywhere on a continent* Feral populations of Domestic Sheep have become established in many parts of the world, notably islands (Nowak 1999). Most reports concerning feral Sheep populations do not specify the particular breed. Reports of feral Merino populations include: **Pacific Ocean Islands:** ▪ <u>Arapawa Island</u> – Merino Sheep were introduced to the island before the 1880s. There are about 100 in a reserve for flora and fauna (Rudge 1984, Lever 1985, Long 2003). ▪ <u>Santa Cruz Island, California Channel</u> – Sheep ranching began in 1850s. By 1857, there were 7000-8000 Sheep, and by 1890 there were about 50,000 on the island. By the 1920s many had become feral and could not be captured, and attempts to regain control of them were abandoned. Many were shot and trapped but despite these efforts many thousands remained in a feral state. The Sheep were mainly Merino with some Rambouillet and Leicester inbred. Between 1979 and 1981 there were about 21,240 Sheep on the island. Sheep were introduced to other California Channel Islands, including San Miguel, Santa Rosa, Anacapa, Santa Barbara, San Nicolas, and Santa Catalina, but have since been extirpated (Leishman 1981, Rudge 1984, Lever 1985, Long 2003). ▪ <u>Catham Islands</u> – Merino Sheep were first reported there in 1900, and there are now two feral flocks: a smaller one on the mainland near the south-west corner, and a larger one on Pitt Island consisting of 2000-3000 animals. They were introduced to Pitt Island in the 1850s and have been feral there for about 70 years (Long 2003). ▪ <u>Hawaiian Islands</u> –Sheep introduced in 1793-94 became well established on Mauna Kea by 1822, and have been there ever since. Lacking natural predators except for wild dogs, the Sheep population reached about 40,000 animals by the early 1930s. Hawaii Territorial foresters built a stock-proof fence around the Mauna Kea Forest Reserve and reduced the population through Sheep drives and hunter-guide programs. Fewer than 500 feral Sheep were left by 1950. Control efforts were then relaxed, and populations increased. There were about 2,000 there in 1976, probably Merino, but also some cross-breeds (Rudge 1984, Lever 1985, Long 2003). **New Zealand** – Sheep introduced to the New Zealand Islands have mostly been Merino breed, or Merino-cross breeds. Sheep have been feral at times in New Zealand since the early 19th century, starting with 5 Australian Merinos imported in 1814. Feral populations were widespread during the 19th century, and have remained feral in some remote areas of both the North and South islands. While formerly widespread on the main islands, at present only eight discrete flocks remain on the mainland, in remote areas, and four flocks on islands (Arapanua, Chatham, Pitt and Campbell). Domestic Sheep occasionally reach places where they cannot be mustered, but generally they are all ewes or wethers and so cannot establish new feral populations (Rudge 1984, Lever 1985, Long 2003). Domestic Sheep were introduced to Campbell Island in 1895, 1901 and 1902 and managed for their wool

		until 1931 when management was discontinued. The Sheep population peaked at 8500 in 1910. When abandoned as a farming venture, some 4000 Sheep where left to run wild. Since 1941 shooting reduced their numbers by about 50 Sheep per year, but the herd was also declining from 1916 up until 1961 at the rate of 5 % annually. About 950-1000 were present in 1961. However, the population had built up to 3000 in 1969, and the island was fenced across the middle in 1970, and 1300 Sheep on the northern half were killed. The Sheep continued to increase in numbers on the southern half of the island, and there were 2861 there in 1977 (Rudge 1984, Lever 1985, Long 2003).
		
		A scientific reserve of $2km^2$ has been created on Pitt Island, Chatham Islands, New Zealand, for around 300 Sheep from a flock thought to be of Merino origin which has been feral for about 70 years. These feral Sheep are regarded as an asset by hunters and fishermen from Pitt and Chatham islands – the meat is appreciated for being sweet, lean, and free for the taking. (Rudge 1983, Rudge 1984, Long 2003).
		
		Australia – few flocks of feral Sheep have ever become established for any length of time. Some occasionally escape into the wild from Sheep stations, but few exist for long. In the late 1920s over 300 Sheep were released in the East Kimberley area of Western Australia, where their descendants survived in a small remnant flock some 40 years later. Today in Australia, feral Sheep are almost unknown (Rudge 1984, Long 2003).
		
		Other introductions where Sheep breed is not known or not specified, that could *be the Merino, include:*
		
		Europe:
		
		Norway and Sweden – A semi-feral population of Sheep existed in southwest Norway where they were protected from hunting, but their presence has not been confirmed recently. A flock of 100 ewes and six rams of a Swedish breed live on Lilla Karlso off Gotland in the Baltic Sea (Rudge 1984, Lever 1985, Long 2003).
		
		Pacific Ocean Islands:
		
		▪ Antipodes – Sheep were present on the islands in 1887, but died out at a later date (Rudge 1984, Lever 1985, Long 2003).
		▪ Auckland Islands
		  – Sheep were introduced a number of times on Auckland Island in the 1840s and 1850s, and again in the 1890s and early 1900s, but failed to become permanently established there (Rudge 1984, Lever 1985, Long 2003).
		  – Released on Adams Island in the 1880s and 1890s, bud did not survive here for more than a few years (Rudge 1984, Lever 1985, Long 2003).
		  – Introduced to Enderby Island in about 1850, and again in the 1890s, but disappeared after a few years, and also to Rose Island in the 1890s (Rudge 1984, Lever 1985, Long 2003).
		▪ San Clemente Island, Channel Islands, US – Early reports list Sheep on the island. They were probably introduced there before 1862, however they no longer occur there (Long 2003).
		▪ Socorro Island –Sheep were brought to the island beginning in 1869, and possibly continuing through the 1880s. They had grown to a population of around 2,000 animals in 1988. Nothing is known of their abundance during intervening years except that they were present in good numbers Today, they survive and prosper as a feral population (Walter and Levin 2008).
		▪ Galapagos Islands – Sheep were introduced to Islabela Island in the 19th century, but it is not known if they were feral Sheep or whether they are now extinct (Rudge 1984, Lever 1985, Long 2003).
		▪ Hawaiian Islands

- Sheep were introduced to Kahoolawe Island in the 18th century, and there are now 300-400 there. Following unsuccessful farming of Sheep on Kahoolawe, about 2000 Sheep were left there in 1859 (Rudge 1984, Lever 1985, Long 2003).

- Juan Fernandez Island (Chile) – Sheep are present, but it is not known if they are feral (Rudge 1984, Lever 1985, Long 2003).
- Kerguelen (France) – Sheep were introduced to Kerguelen in 1909. Some were imported to Ile Longue, and in 1911, 1000 were liberated on Presque'Ile Bouquet de la Grye. Those Sheep on the islands were largeley maintained by shepherds, but this venture was interrupted between 1914 and 1921, but recommenced at Port Couvreaux and Ile du Corbeau until abandoned in 1932. Some Sheep were also landed on Ile Mussel in 1952. Some Sheep escaped to Grande Terre while they were being moved before slaughter, and in 1973 about 70 were living wild there. The Sheep here are a mixed race, dominant type 'Bizet' (Rudge 1984, Lever 1985, Long 2003).
- Macquarie Island – Sheep were introduced in 1947 and a flock of 15 was kept on the island, but they did not become established as a feral species (Lever 1985).
- Society Islands – Captain Cook gave Sheep to the natives on Otaheite in the Society Islands, but they died before they could become established (Rudge 1984, Lever 1985, Long 2003).

Indian Ocean Islands

- New Amsterdam (France) – A small flock of Sheep existed on the island in 1957 (Rudge 1984, Lever 1985, Long 2003).
- St Paul – Sheep were imported to the island some time before 1961, but are not numerous there (Rudge 1984, Lever 1985, Long 2003).
- South Georgia – Sheep have at times lived on the island, but are not established there now (Rudge 1984, Lever 1985, Long 2003).
- Tristan da Cunha – Sheep were introduced to the island in 1824. Some were present there in 1829, and in 1938 there were seven on Inaccessible Island. During the 1940s and 1950s they were grazed on Tristan where they were only partly confined. The residents left the island and 740 Sheep in 1961 when a volcano erupted, but before their return in 1963, dogs which had also been left behind ran wild and killed most of the Sheep (Rudge 1984, Lever 1985, Long 2003).
- Marion and Prince Edward Islands – Sheep were imported in 1927, but failed to become established (Rudge 1984, Lever 1985, Long 2003).
- Gough Island – Sheep were introduced to the island in 1956, but are confined in enclosures (Rudge 1984, Lever 1985, Long 2003).

North America

- Canada – Sheep are run on some of the larger islands off British Colombia, and sometimes are feral. They were introduced at some time in the 19th century, and occurred on Lasqueti Island, Saltspring Island, Chatham Island, DeCourcey Island, and Saturna Island (British Colombia) in the 1980s (Rudge 1984, Lever 1985, Long 2003).
- United States (mainland)
  - Small feral flocks, of less than a dozen or so Sheep, may still exist in: the Split Mountain Gorge in north-eastern Utah; Southern Ute Indian Reservation in south-west Colorado; Jefferson County in Oregon; and Morgan County in northern Alabama. Little is known of their origin (Rudge 1984, Lever

		1985, Long 2003). – Experimental Sheep (Mouflon x Rambouillet) are still present in numbers in Texas (no information on whether these are feral or on farms/ranches) (Rudge 1984, Lever 1985, Long 2003). – Sheep do not persist in California probably because of the presence of large predators (Rudge 1984, Lever 1985, Long 2003). **West Indies** ▪ Hispaniola – Wild Sheep were reported at Anse-a-Pitres in 1797-98, but there were none present in Haiti in the early 1950s (Rudge 1984, Lever 1985, Long 2003). ▪ Puerto Rico – Feral Sheep were present on Salt Island, but have since disappeared because the vegetation has gone (Rudge 1984, Lever 1985, Long 2003). **Atlantic Ocean Islands** Sao Tome and Principe – Located in the Gulf of Guinea in the Atlantic Ocean. It is likely that Sheep arrived with the first settlers in the late 1400s, and introductions continued as agricultural expansion and settlement increased. When they were allowed to become feral is unknown (Dutton 1994).
*B2/4. Exotic population established overseas of the **Damara Sheep breed** (0–4*	0	*No exotic population ever established* Feral populations of Domestic Sheep have become established in many parts of the world, notably islands (Nowak 1999). Most reports concerning feral Sheep populations do not specify the particular breed. No specific reports on feral populations of Damara Sheep found (Lever 1985, Long 2003). No score has been recorded for Damara exotic population.
*B2/5. Exotic population established overseas of the **Dorper Sheep breed** (0–4*	0	*No exotic population ever established* Most reports concerning feral Sheep populations do not specify the particular breed. No specific reports on feral populations of Dorper Sheep found (Lever 1985, Long 2003). As the Dorper Sheep breed was developed during the 1930s, it is unlikely that feral populations of sheep that exist today are of this breed. No score has been recorded for the presence of Dorper exotic populations.
*B3/1. Overseas range size (0–2) - **introduced overseas distribution*** for ***Domestic Sheep (no breeds distinguished)*** as no natural populations exist in the wild. < 1 = 0; 1 – 70 = 1; >70 = 2	1	*Overseas range size between 1-70 million km^2, estimated at 2.68 million km^2. Includes current and past 1000 years, natural and introduced range.* The Domestic Sheep *Ovis aries* occurs worldwide in association with people (Nowak 1999) but it is not considered to occur in a natural free-range state, except for worldwide introduced populations (Long 2003) (detailed in question B2 above). The calculated range size of 2.68 million km^2 is based on these introduced feral populations. **Additional information** In Norway, domestic sheep are farmed under free-range conditions at certain times of the year. Lambs are born during late winter or spring, and sheep and lambs graze on fenced farmland before being released to free-range in open forested or alpine ranges. In September they are returned to fenced farmland and after a period of autumn grazing animals are barned and fed indoors. Owners without adequate land for spring grazing let the animals out on the open range pastures directly from their in-house feeding. In coastal areas of Norway, sheep can graze outdoors all year round, Other farmers may have abundant pasture and/or few animals, and can allow them to remain on the fenced pasture for the whole season (Asheim and Mysterud 2004, 2008). Extensive sheep farming, in which sheep are left largely unsupervised, occurs in Central France (Dedieu and Chabosseau 2008) and the French Jura (Stahl et al 2002), the Karoo area in South Africa (Palmer and

		Ainslie 2002, Henning 2008, SouthAfrica.info 2008), and pastoral regions in Australia (Australian Natural Resources Atlas 2007). Extensive sheep farming does occur elsewhere, such as in North America; however, information separating regions that practise extensive type farming and those that practise semi-intensive or intensive farming could not be found, therefore those regions were not included in the climate match analysis.
B3/2. Overseas range size (0–2) - for the ***Domestic Sheep's ancestor's (the Mouflon) natural distribution*** < 1 = 0; 1 – 70 = 1; >70 = 2	1	*Overseas range size between 1-70 million km^2, estimated at 2.21 million km^2.* **Historical distribution** Available chromosomal and archaeological evidence indicates that the **Asiatic Mouflon** (*Ovis orientalis*) of Iran and Asia Minor is the most likely ancestor of the present day domestic sheep. Domestication occurred about 9,000-11,000 years ago in the region between the eastern Mediterranean and Caspian Sea. However, this ancestry has not been accurately determined. Sheep were probably first domesticated in south-west Asia or the Middle East. Bone remains as old as 8,000 years were recovered in western France in 1985. *Ovis* bones, in association with human settlement, have been found back to the Neolithic time 5000 BC (Lever 1985, Corbet and Harris 1991, Adams and McKinley 1995, Nowak 1999, Long 2003).
B3/3. Overseas range size (0–2) - for the ***Merino Sheep breed's introduced overseas distribution*** < 1 = 0; 1 – 70 = 1; >70 = 2	1	*Overseas range size between 1-70 million km^2 , estimated at 1.07 million km^2.* **Merino** - The Merino Sheep has been introduced worldwide, and has established feral populations in some places (Long 2003), as described in B2.
B3/4. Overseas range size (0–2) - for the ***overseas distribution where Damara Sheep breed was developed*** < 1 = 0; 1 – 70 = 1; >70 = 2	0	*Overseas range size less than 1 million km^2, estimated at 0.51 million km^2.* **Damara** – This breed was farmed in isolation in a region of Namibia and remained free of genetic influence from other breeds. Herding of Damara sheep, with few external influences, continues to be carried out in northwestern Namibia and southern Angola by the local inhabitants (Department of Animal Science 2007). Until about the third or fourth century AD, there was no known herding of domesticated animals in this region. During the fourth century tribes of Hamitic descent, migrated into nearby areas of southern Africa, bringing with them a type of sheep that probably originated centuries before in Egypt and the Middle East. The Damara is descended principally from this breed (type) (Griffith 1998). There are no reports of flocks of Damara sheep occurring in the wild. It is unlikely that Damara were introduced to any of the islands where feral populations of sheep occur today, due to the fact that the breed remained in isolation in Namibia for many years [see (Long 2003)]. For a comparison of climate analysis with Merino and Dorper, a distribution using the farming areas of Namibia and Angola (where the breed was developed) has been mapped (Map 4).
B3/5. Overseas range size (0–2) - for the ***overseas distribution where Dorper Sheep breed was developed*** < 1 = 0; 1 – 70 = 1; >70 = 2	1	*Overseas range size between 1-70 million km^2, estimated at 1.09 million km^2.* **Dorper** – The breed was developed for high lamb production in the arid, extensive areas of southern Africa during the 1930s, by crossing the Dorset Horn and the Blackheaded Persian. The breed was very successful, and became numerically the second most important sheep in South Africa (Schoeman 2000). (Milne 2000, Department of Animal Science 2007). There are no reports of Dorper sheep occurring in the wild. Most introductions of sheep to islands occurred before the 1930s or just after so it is very unlikely that the Dorper was among the sheep placed on islands by people. For a comparison of climate analysis with Merino and Damara, a distribution using the Southern Africa (where the breed was developed) has been mapped (Map 5).

B4/1. Taxonomic Class for the ***Domestic Sheep (no breeds distinguished)*** *(0–1)*	1	*Mammal* (ITIS Integrated Taxonomic Information System 2007, Catalogue of Life 2008).
B4/2. Taxonomic Class for the ***Domestic Sheep's ancestor (the Mouflon)*** *(0–1)*	1	*Mammal* (ITIS Integrated Taxonomic Information System 2007, Catalogue of Life 2008).
B4/3. Taxonomic Class for the ***Merino Sheep breed*** *(0–1)*	1	*Mammal* (ITIS Integrated Taxonomic Information System 2007, Catalogue of Life 2008).
B4/4. Taxonomic Class for the ***Damara Sheep breed*** *(0–1)*	1	*Mammal* (ITIS Integrated Taxonomic Information System 2007, Catalogue of Life 2008).
B4/5. Taxonomic Class for the ***where Dorper Sheep breed*** *(0–1)*	1	*Mammal* (ITIS Integrated Taxonomic Information System 2007, Catalogue of Life 2008).
B. ESTABLISHMENT RISK SCORE **SUM OF B1-4 (1-13)** **1. DOMESTIC SHEEP (NO BREEDS DISTINGUISHED)**	**8**	
B. ESTABLISHMENT RISK SCORE **SUM OF B1-4 (1-13)** **2. DOMESTIC SHEEP'S ANCESTOR (MOUFLON)**	**4**	
B. ESTABLISHMENT RISK SCORE **SUM OF B1-4 (1-13)** **3. MERINO SHEEP BREED**	**8**	
B. ESTABLISHMENT RISK SCORE **SUM OF B1-4 (1-13)** **4. DAMARA SHEEP BREED**	**3**	
B. ESTABLISHMENT RISK SCORE **SUM OF B1-4 (1-13)** **5. DORPER SHEEP BREED**	**6**	
Model 2: Seven-factor model for birds and mammals (BOMFORD 2008)		
B5/1. Diet of the ***Domestic Sheep (no breeds distinguished)*** *(0–1)*	1	*Generalist with a broad diet of many food types* Sheep may feed intermittently throughout the day or rest during the hottest hours, and they are occasionally active at night. Sheep are generalist herbivores, consuming a variety of plants according to availability and type. The diet consists largely of grasses, pasture, shrubs, herbs, leaves, sedges, forbs, with some browse included (Van Vuren and Coblentz 1987, Nowak 1999, Long 2003, King 2005).
B5/2. Diet of the ***Domestic Sheep's ancestor (the Mouflon)*** *(0–1)*	1	*Generalist with a broad diet of many food types* The Mouflon is herbivorous, feeding on grasses and shrubs, and also grains (IUCN 2009).
B5/3. Diet of the ***Merino Sheep breed*** *(0–1)*	1	*Generalist with a broad diet of many food types* A study of the diet of Merino Sheep in a semi-arid (*Eucalyptus populnea*) woodland in Australia found that virtually all herbaceous species proved edible at some time, but young ephemeral herbs were most

		preferred, followed by new growth on perennial grasses. When these foods were depleted, sheep subsisted on dead perennial grass, leaf litter, and Hopbush (*Dodonaea viscosa*) (Harrington 1986).
B5/4. Diet of the ***Damara Sheep breed*** *(0–1)*	1	*Generalist with a broad diet of many food types* This breed has a diverse diet, feeding on grass, bush, cereal stubbles, shrubs and trees (Damara Sheep Breeders' Society of South Africa 2001, Department of Animal Science 2007).
B5/5. Diet of the ***Dorper Sheep breed*** *(0–1)*	1	*Generalist with a broad diet of many food types* The Dorper is a non-selective grazer and grazes on a greater number of plant species than Merino sheep. They graze in a similar manner to a goat and have the ability to graze at a higher height level than traditional sheep (Department of Animal Science 2007, New Zealand Sheepbreeders' Association 2007). Dorper sheep largely utilise shrubs and bushes, and grass to a lesser extent (Du Toit 1998, Brand 2000).
B6/1. ***Domestic Sheep (no breeds distinguished)*** *lives in disturbed habitat (0–1)*	1	*Can live in disturbed habitats* The species is extremely versatile and can occur in a wide variety of habitats worldwide from sea level to greater than 2000 m. Habitat types include rough pasture, bush, scrub, forest, and grasslands (Long 2003, King 2005, Global Invasive Species Database 2006). **Merino** – the breed has the ability to flourish in extremes of weather and environment (The American Delaine & Merino Record Association 2008). **Damara** – can survive in harsh environments and under poor nutritional conditions. The breed is considered exceptionally vigorous and can produce and reproduce where water and grazing is fairly restricted. It does, however, respond very well to optimum conditions (Department of Animal Science 2007). The breed thrives in areas where other breeds will loose condition. it can occur in desert regions as well as those areas that experience snow and winter temperatures below zero. It also thrives in extensive farming areas (Damara Sheep Breeders' Society of South Africa 2001). **Dorper** – this breed is extremely hardy and is well adapted to a variety of climatic and grazing conditions. It can thrive where other breeds can barely exist (Brand 2000, Farm Diversification Information Service and Castleman 2000, Milne 2000, Higham 2002, Department of Animal Science 2007, Schoenian 2007, DSSA 2008). It can adapt to any environment, and either hot or cold climate (New Zealand Sheepbreeders' Association 2007). The breed has the ability to flourish, grow and reproduce in irregular and low rainfall environments. The thick skin also protects the sheep under harsh climatic conditions (Farm Diversification Information Service and Castleman 2000).
B6/2. ***Domestic Sheep's ancestor (the Mouflon)*** *lives in disturbed habitat (0–1)*	1	*Can live in disturbed habitats* The Mouflon inhabits arid habitats, especially grasslands, but also occur in agricultural fields and woodland areas (IUCN 2009). The species inhabits low, open country that is also used intensively by people and livestock (Shackleton 1997) as cited in (Nowak 1999).
B6/3. ***Merino Sheep breed*** *lives in disturbed habitat (0–1)*	1	*Can live in disturbed habitats* The breed has the ability to flourish in extremes of weather and environment (The American Delaine & Merino Record Association 2008).
B6/4. ***Damara Sheep breed*** *lives in disturbed habitat (0–1)*	1	*Can live in disturbed habitats* Can survive in harsh environments and under poor nutritional conditions. The breed is considered exceptionally vigorous and can produce and reproduce where water and grazing is fairly restricted. It does, however, respond very well to optimum conditions (Department of Animal Science 2007). The breed thrives in areas where other breeds will loose condition. it can occur in desert regions as well as those areas that

		experience snow and winter temperatures below zero. It also thrives in extensive farming areas (Damara Sheep Breeders' Society of South Africa 2001).
B6/5. ***Dorper Sheep breed*** *lives in disturbed habitat (0–1)*	1	*Can live in disturbed habitats* This breed is extremely hardy and is well adapted to a variety of climatic and grazing conditions. It can thrive where other breeds can barely exist (Brand 2000, Farm Diversification Information Service and Castleman 2000, Milne 2000, Higham 2002, Department of Animal Science 2007, Schoenian 2007, DSSA 2008). It can adapt to any environment, and either hot or cold climate (New Zealand Sheepbreeders' Association 2007). The breed has the ability to flourish, grow and reproduce in irregular and low rainfall environments. The thick skin also protects the sheep under harsh climatic conditions (Farm Diversification Information Service and Castleman 2000).
B7/1. Non-migratory behaviour by ***Domestic Sheep (no breeds distinguished)*** *(0–1)*	1	*Non-migratory or facultative migrant in its native range* Feral sheep are sedentary; the home range may be up to 0.45 km^2 (Long 2003). Sheep are gregarious and have a highly developed herding instinct. They will gather in large flocks, sometimes of more than 100 individuals moving over an area in groups, rather than as individuals. Sheep become considerably stressed when separated from flock members. Sheep will form separate flocks of females and young, and of rams as they usually remain apart except during the rut, at which time the highest-ranking males are able to mate with the oestrous females (Nowak 1999, Reavill 2000, Long 2003).
B7/2. Migratory behaviour (0–1) by the ***Domestic Sheep's ancestor (the Mouflon)*** *(0-1)*	0	*Always migratory in its native range* Most wild sheep populations undergo seasonal movements, generally dispersing upward and over a larger area during the summer, and concentrating in sheltered valleys during the winter (Eslami et al 1979, Nowak 1999)
B7/3. Non-migratory behaviour by the ***Merino Sheep breed*** *(0–1)*	1	*Non-migratory or facultative migrant in its native range* Feral sheep are sedentary; the home range may be up to 0.45 km^2 (Long 2003). Sheep are gregarious and have a highly developed herding instinct. They will gather in large flocks, sometimes of more than 100 individuals moving over an area in groups, rather than as individuals. Sheep become considerably stressed when separated from flock members. Sheep will form separate flocks of females and young, and of rams as they usually remain apart except during the rut, at which time the highest-ranking males are able to mate with the oestrous females (Nowak 1999, Reavill 2000, Long 2003).
B7/4. Non-migratory behaviour by the ***Damara Sheep breed*** *(0–1)*	1	*Non-migratory or facultative migrant in its native range* Feral sheep are sedentary; the home range may be up to 0.45 km^2 (Long 2003). Sheep are gregarious and have a highly developed herding instinct. They will gather in large flocks, sometimes of more than 100 individuals moving over an area in groups, rather than as individuals. Sheep become considerably stressed when separated from flock members. Sheep will form separate flocks of females and young, and of rams as they usually remain apart except during the rut, at which time the highest-ranking males are able to mate with the oestrous females (Nowak 1999, Reavill 2000, Long 2003).
B7/5. Non-migratory behaviour by the ***Dorper Sheep breed*** *(0–1)*	1	*Non-migratory or facultative migrant in its native range* Feral sheep are sedentary; the home range may be up to 0.45 km^2 (Long 2003). Sheep are gregarious and have a highly developed herding instinct. They will gather in large flocks, sometimes of more than 100 individuals moving over an area in groups, rather than as individuals. Sheep become considerably stressed when separated from flock members. Sheep will form separate flocks of females and young, and of rams as they usually remain apart except during the rut, at which time the

		highest-ranking males are able to mate with the oestrous females (Nowak 1999, Reavill 2000, Long 2003).
B. Establishment Risk Score **Sum of B1-7 (1–16)** **1. Domestic Sheep (no breeds distinguished)**	**11**	
B. Establishment Risk Score **Sum of B1-7 (1–16)** **2. Domestic Sheep's ancestor (Mouflon)**	**6**	
B. Establishment Risk Score **Sum of B1-7 (1–16)** **3. Merino Sheep breed**	**11**	
B. Establishment Risk Score **Sum of B1-7 (1–16)** **4. Damara Sheep breed**	**6**	
B. Establishment Risk Score **Sum of B1-7 (1–16)** **5. Dorper Sheep breed**	**9**	
STAGE C: PROBABILITY AN ESTABLISHED SPECIES WILL BECOME A PEST Part C has been completed using the climate analysis based on the introduced or feral range of domestic sheep (B1). No attempt has been made to distinguish different pest risk for the merino, damara and dorper breeds.		
C1. Taxonomic group (0–4)	4	*Mammal in one of the orders that have been demonstrated to have detrimental effects on prey abundance and/or habitat degradation,* Order Artiodactyla, *AND mammal in one of the families that are particularly prone to cause agricultural damage* Family Bovidae (Catalogue of Life 2008).
C2. Overseas range size including current and past 1000 years, natural and introduced range (0–2)	0	*Overseas range less than 10 million km^2. Estimated at 2.68 million km^2*, based on introduced feral populations as no natural populations exist in the wild. No natural distribution, with introduced populations occurring worldwide (Long 2003) (see B2 and B7 for details).
C3. Diet and feeding (0–3)	3	*Mammal that is primarily a grazer or browser* Sheep will graze and browse, consuming a variety of plant material (Nowak 1999) (see B5 for details).
C4. Competition with native fauna for tree hollows (0–2)	0	*Does not use tree hollows* No information suggesting any sheep species or breeds use tree hollows (Nowak 1999).
C5. Overseas environmental pest status (0–3)	2	*Moderate environmental pest in any country or region*

Has the species been reported to cause declines in abundance of any native species of plant or animal or cause degradation to any natural communities in any country or region of the world?		**Effects on native animal species:** Feral populations of sheep have contributed to the extinction and endangerment of numerous native species. The domestic sheep has adversely affected its wild relatives in many areas by competing for forage and spreading disease (Nowak 1999). Continued degradation of the Mamane woodland in Mauna Kea, Hawaii in the late 1970s posed a significant threat to the Palila (*Loxioides bailleui*), an endangered endemic Hawaiian bird now found only in the subalpine woodland of Mauna Kea. Palila depend on Mamane trees and to a lesser extent on Naio trees, for food and nest sites (Scowcroft and Giffin 1983, Scowcroft and Sakai 1983, Scowcroft and Conrad 1992). On Santa Cruz Island, California, habitat loss from overgrazing by feral sheep may be affecting nesting sea birds such as the Xantus' Murrelet (*Synthliboramphus hypolecus*), that often nests under shrubs or shrub-like vegetation. The Murrelet probably suffered similarly on Anacapa, Santa Barbara, San Benitos, Todos Santos, and Guadalupe islands. Sheep may also trample habitat and nesting burrows (McChesney and Tershy 1998). Changes to plant community structure through depletion of the herbaceous layer, defoliation of the lower branches of shrubs, and reduction of shrub density has also affected native birds. Sheep grazing was associated with an average 63% reduction in density of six insular endemic bird species (Van Vuren and Coblentz 1987). In sheep-impacted areas of Socorro Island, Baja California peninsula, endemic avifauna like the Socorro Parakeet (*Aratinga brevipes*) has declined, and four small songbirds have disappeared or declined. An example of the indirect effect of feral sheep on natural environments, the Mourning Dove (*Zenaida macroura*) and the Northern Mockingbird (*Mimus polyglottos*) have self-invaded Socorro; usually absent from undisturbed pristine and dense habitats, these birds prefer the open habitats that have been created by sheep overgrazing (Walter and Levin 2008). In New Zealand, the Giant Snail (*Powelliphanta hochstetteri*) that requires deep humid litter for food and shelter has been affected by destruction of vegetation due to sheep trampling. On Pitt Island, sheep (and cattle) also prevent regeneration and disturb the nesting areas of burrowing petrels SPECIES NAME (Long 2003, King 2005). In a 5-year video study of the causes of mortality of 3 species of ground nesting birds of braided rivers of the Upper Waitaki Basin (South Island, New Zealand), sheep trampled 2 of the 11 Banded Dotterel (*Charadrius bicinctus*) nests on the only site to which sheep had access. The adult dotterels displayed vigorously in front of the slowly approaching sheep, but had no apparent affect on them. It is suggested that sheep and other stock have the potential to cause much greater mortality than was observed in this study (Sanders and Maloney 2002). **Effects on native vegetation:** ***Browsing damage*** Over-browsing by domestic farm-sheep on Easter Island is believed to have been responsible for the extinction of the island's only native tree, *Sophorna toromiro* (Lever 1985) In areas of Mauna Kea, Hawaii, where sheep are now restricted, the release from grazing pressure has benefited native species in tree line communities, especially those that are highly palatable and highly susceptible to damage (including Mamane *Sophora chrysophylla*) (Scowcroft and Giffin 1983, Scowcroft and Sakai 1983, Scowcroft and Conrad 1992). Changes in vegetation since the introduction of sheep on Santa Cruz are indicated by historical accounts and old photographs. These demonstrate significant reduction of coastal sage scrub, and also depletion of several chaparral shrubs, especially Chamise (*Adenostema fasciculatum*). Grazing by feral sheep on Santa

		Cruz during the last 130 years has been the major cause of the substantial reduction of vegetation, causing moderate to severe impact of about half of the island (Brumbaugh et al 1982, Long 2003). A survey of about 85 % of the island revealed that almost 80 km^2 (36 % of the area surveyed) could be classified as heavily impacted by sheep. Such areas were characterised by herbaceous vegetation mostly or entirely consumed, shrubs stripped of all leaves within reach of the sheep, sheep trails worn to or below ground level, and extensive areas of stripped, eroded soil (Van Vuren and Coblenz 1984). Vegetation has recovered wherever sheep have been successfully excluded during the last 25 years, and regeneration of coastal sage is occurring on some portions of the island (Brumbaugh et al 1982, Long 2003). Overgrazing by feral sheep may affect vegetation by indirectly altering hydrologic processes and affect species that are dependent on these processes. A study of the impacts of feral sheep on watershed systems on Santa Cruz Island found that overgrazing had a marked effect on stream flow. Flow was much greater in overgrazed than in lightly grazed watersheds early in the rainy season, but the difference vanished later in the season. This pattern can be explained by reduced infiltration and increased surface runoff of rainfall in overgrazed areas (Van Vuren et al 2001). In areas of New Zealand subjected to 80 years grazing by sheep, most Snow Tussocks (*Chionochloa* spp.) have been destroyed. Those remaining are predominantly senescent, and seedlings are infrequent. Areas that have been free from sheep grazing for more than 21 years have high proportions of seedlings and juvenile Snow Tussocks, and low proportions of senescent tussocks (Rose and Platt 1992). Since a fence was erected across the middle of Campbell Island, New Zealand in 1970, there has been some spectacular recovery of the vegetation in the northern half where the sheep have been removed, and the area is now a reserve for fauna and flora. Closely grazed sward was replaced in many places by large endemic herbs (e.g. *Anisotome* spp., *Stilbocarpa polaris*, *Pleurophyllum* spp.), and by the palatable tussock grasses *Poa foliosa* and *Chionochloa antarctica* (Dilks and Wilson 1979, Meurk 1982, Long 2003, King 2005). In forest on Arapawa Island, sheep (together with goats and pigs) prevented regeneration and damaged the forest floor with their hooves (Long 2003, King 2005). ***Trampling damage*** On Mauna Kea, Hawaii, feral sheep are frequently reported to be destructive to plant forms and to cause soil erosion. By suppressing tree reproduction over large areas, the soil is exposed to accelerated erosion (Scowcroft and Giffin 1983, Scowcroft and Sakai 1983, Scowcroft and Conrad 1992, Long 2003). On Santa Cruz Island, California, feral sheep had a significant impact on vegetation, by causing erosion, and soil compaction (McChesney and Tershy 1998). Long-term overgrazing by feral sheep has resulted in moderate to severe ecological impacts to about one-half of Santa Cruz Island. Effects of sheep on a grassland community included reduced herbaceous cover, increased bare ground, altered community structure, increased erosion, and decreased leaf litter, which promotes subsequent growth. The creation of trails or tracks from the movement of sheep along regular pathways stripped 7% of some areas of vegetation (Van Vuren and Coblentz 1987). On Socorro Island, Baja California peninsula, the sheep-impacted half of the island has been transformed into savannah and prairie-like open habitats that are covered by a mix of native and exotic vegetation, surrounded by severe erosion. The sheep-free half of the island has maintained a pristine shrub and forest vegetation, and there is no soil erosion (Walter and Levin 2008). At Qinghai Lake, Qinghai-Tibet Plateau, China, domestic sheep are the most important food competitor of the critically endangered Przewalski's Gazelle (*Procapra przewalskii*). Dietary overlap between Przewalski's Gazelle and sheep ranged from 61% during the plant-growing period, to 81% during the plant-withering period, indicating severe food competition (Liu and Jiang 2004). **Beneficial effects**

		In southwestern Mauna Kea, Hawaii, some native birds have adapted to the use of sheep wool as a nesting material. Three species have been observed to use wool extensively in nest construction. The Palila (*Loxioides bailleui)* had wool in 22.2% of its nests; the Amakihi (*Loxops virens*), one of the two most abundant endemic birds, incorporated wool into 33.3% of its nests; and the Elepaio (*Chasiempis sandwichensis*) showed the greatest usage, using wool in 60.9% of its nests. Sheep wool appears to be a sought-after nesting material in two species, as both the Amakihi and Elepaio will travel outside their territories to obtain wool for nest construction (van Riper III 1975). Feral sheep may not pose a serious threat to the Southern Royal Albatross (*Diomeaea epomophora*) on Campbell Island, New Zealand, and sheep browsing may have increased the area suitable for nest sites. In 1969, about 4400 nesting pairs of Royal Albatross and 3000 feral sheep were counted on the island. Albatrosses had increased by 90% since 1958, and sheep by over 200% since 1961 (Taylor et al 1970). Sheep are a source of food for a variety of predators including Red Fox (*Vulpes vulpes*), Lynx (*Lynx lynx*), Golden Eagle (*Aquila chrysaetos*), Wolf (*Canis lupus*), Brown Bear (*Ursus arctos*) and Wolverine (*Gulo gulo*) (Warren et al 2001, Moa et al 2006, Bostedt and Grahn 2007, Namgail et al 2007). However, this may also be viewed as an indirect negative effect, as depredation on sheep by these species generates hostility from farmers, and several of these species are currently listed as threatened species.
C6. Climate match to areas with susceptible native species or communities (0–5) Identify any native Australian animal or plant species or communities that could be susceptible to harm by the exotic species if it were to establish a wild population here.	5	*One or more susceptible native species or ecological communities that are listed as vulnerable or endangered under the Australian Government Environment Protection and Biodiversity Conservation Act 1999 has a restricted geographical range that lies within the mapped area of the highest six climate match classes for the exotic species being assessed.* Reference for all vulnerable or endangered species and communities (status noted in bold) (Dept of the Environment Water Heritage and the Arts 2007, Dept of the Environment Water Heritage and the Arts 2008) Susceptible Australian native species or natural communities that could be threatened include birds that nest on or close to the ground, and vegetation which may be overgrazed by sheep or trampled: **Birds: Endangered** – Chestnut-rumped Heathwren (Mt Lofty Ranges) (*Hylacola pyrrhopygia*), Southern Emu-wren (*Stipiturus malachurus*); **Vulnerable** – Noisy Scrub-bird (*Atrichornis clamosus*), Western Bristlebird (*Dasyornis longirostris*) (Pizzey and Knight 1997, Barrett et al 2003). **Plants: Critically endangered –** Native Wintercress (*Barbarea australis*), spider-orchids (*Arachnorchis* spp.), Thick-stem Caladenia (*Petalochilus campbellii*), Forest Fingers (*P. sylvicola*), Robust Fingers (*P. tonellii*), Kilsyth South Spider-orchid (*Caladenia sp. Kilsyth South (G.S.Lorimer 1253)*), Blue Tinsel Lily (*Calectasia cyanea*), Brindabella Midge-orchid (*Corunastylis ectopa*), Bearded Heath (*Epacris barbata*), Border Heath (*E. limbata*), Stuart's Heath (*E. stuartii*), Davies' Waxflower (*Phebalium daviesii*), Freycinet Waxflower (*Philotheca freyciana*), leek-orchids (*Prasophyllum* spp.). **Endangered** – spider-orchids (*Arachnorchis* spp.), Roadside Wallaby Grass (*Austrodanthonia popinensis*), Striped Pink Fingers (*Caladenia carnea* var. *subulata*), Coast Spider-orchid (*C. conferta*), White Rabbits (*Petalochilus xantholeucus*), Apsley Heath (*Epacris apsleyensis*), Funnel Heath (*E. glabella*), Grand Heath (*E. grandis*), Pretty Heath (*E. virgata*), Scrambling Ground-fern (*Hypolepis distans*), Adamson's Blown-grass (*Lachnagrostis adamsonii*), Spalding Blown Grass (*L. limitanea*), Stirling Range Beard Heath (*Leucopogon gnaphalioides*), Drummond's Grass (*Deyeuxia drummondii*), Small Golden Moths Orchid (*Diuris basaltica*), Bald-tip Beard-orchid (*Calochilus richiae*). **Vulnerable** – Shining Cudweed (*Argyrotegium nitidulus*), Limestone Spider-orchid (*Arachnorchis calcicola*), Elegant Spider-orchid (*A. formosa*), Candy Spider-orchid (*A. versicolor*), Woolcock's Spider-orchid (*A. woolcockiorum*), Narrow-leaf Bent-grass (*Deyeuxia pungens*), Reflexed Everlasting (*Ozothamnus reflexifolius*), Salt-lake Tussock-grass (*Poa sallacustris*), River Swamp Wallaby-grass (*Amphibromus*

		fluitans), Ornate Pink Fingers (*Petalochilus ornatus*). **Communities:** Eastern Stirling Range Montane Heath and Thicket **(endangered)**, Iron-grass Natural Temperate Grassland of South Australia **(critically endangered)**.
C7. Overseas primary production pest status (0–3) *Has the species been reported to damage crops or other primary production in any country or region of the world?*	1	*Minor pest of primary production in any country or region* The domestic sheep is one of the most economically significant species in the world. Since domestication, sheep have been a source of meat, milk, wool and hides in nearly every country in the world. In some cultures, sheep are highly valued as a sacrificial animal. The versatility of the species contributes to its economic significance, as large herds can be maintained under various conditions in many environments at relatively low cost (Nowak 1999, Reavill 2000). Wool contamination, whereby white wool is mixed with pigmented and/or highly medullated fibre, can occur when sheep, such as the Merino, are cross-bred or mixed with coloured or highly medullated sheep types. Wool contamination with this fibre can cause a significant reduction in the value of the wool (Fleet 2008, WoolProducers Australia 2008). Feral sheep breeding or mixing with domestic sheep have the potential to cause wool contamination. **New Zealand:** Feral sheep can create a local nuisance by mixing with domestic stock and potentially interfering with breeding lines as well as transmit disease and spread ectoparasites (Long 2003, King 2005). **Hawaii:** Overgrazing by domestic and feral sheep has caused soil erosion, creating poor habitat range for two introduced pheasant species. Sheep also compete with the pheasants for food. The pheasants were first introduced to the Hawaiian islands in the 1800s and they are a popular and valuable game-animal as well as the plumage being highly prized for feathers used in the manufacture of hatbands or “leis” worn as an island custom. At present there are 2 species, the Ring-necked Pheasant *Phasianus colchicus torquatus* and the Green or Versicolor Pheasant *P. versicolor* plus their hybrids established in the Hawaiian Islands (Schwartz and Schwartz 1951).
C8. Climate match to susceptible primary production (0–5) *Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9.*	5	Score = 279 (Bomford 2003, 2006) See Commodity Scores Table – Species has attributes making it capable of damaging sheep, cattle, timber, cereal grain, oilseed, grain legume, other livestock, and other horticultural commodities.
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)	1	*$1.00-10 million* Feral sheep could cause considerable damage to ornamental gardens by grazing and trampling; and may also cause damage to cars due to sheep-vehicle collisions.
C11. Harm to people (0–5) *Assess the risk that, if a wild population established, the species could cause harm to or annoy people. Aggressive behaviour, plus the possession of organs capable of inflicting harm, such as sharp teeth, tusks, claws, spines, a sharp bill, horns, antlers or toxin-delivering organs may enable animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account (see Stage A, Score A1).*	3	*Moderate risk – injuries or harm likely to be moderate but unlikely to be fatal and few people at risk* Medium-sized mammal with horns. Rams often head-butt during the rutting season (Schoenian 2007). No reports of attacks on humans by feral sheep but serious injury and death has occurred as a result of domestic sheep and human interactions, rams in particular can cause serious injury to people and other animals (Animal Attack Files 2000, BBC News 2006, Schoenian 2007). Damara ewes have been known to fight off predators when attacked to protect their lambs (Department of Animal Science 2007). **Zoonoses:** Sheep are hosts of a range of zoonotic diseases. Risk of disease transmission from populations of feral sheep is very low.

		Zoonotic diseases of sheep include: Cryptosporidiosis, Q-Fever, Fascioliasis, Trichostrongylidiosis, Salmonella, Dermatophilosis, Pasteurellosis, Orf , Myiasis [Information on zoonoses obtained from: (Stevenson and Hughes 1988)]. For further information see Appendix 1.
C. Pest Risk Score **Sum C 1 to 11 (1–37)**	**26**	
Stage A. Public Safety Risk Rank – risk to public safety posed by captive or released individuals 0 = Not dangerous; 1 = Moderately dangerous; ≥ 2 = Highly dangerous	**1**	**Moderately Dangerous**
Stage B. Establishment Risk Rank – risk of establishing a wild population **Model 1: Four-factor model for birds and mammals (Bomford 2008)** ≤ 5 = low establishment risk; 6-8 = moderate establishment risk; 9-10 = serious establishment risk; ≥11-13 = extreme establishment risk		
1. Domestic Sheep (no breeds distinguished)	**8**	**Moderate Establishment Risk**
2. Domestic Sheep's ancestor (Mouflon)	**4**	**Low Establishment Risk**
3. Merino Sheep breed	**8**	**Moderate Establishment Risk**
4. Damara Sheep breed	**3**	**Low establishment Risk**
5. Dorper Sheep breed	**6**	**Moderate Establishment Risk**
Stage B. Establishment Risk Rank – risk of establishing a wild population **Model 2: Seven-factor model for birds and mammals (Bomford 2008)** ≤ 6 = low establishment risk; 7-11 = moderate establishment risk; 12-13 = serious establishment risk; ≥14 = extreme establishment risk		
1. Domestic Sheep (no breeds distinguished)	**11**	**Moderate Establishment Risk**
2. Domestic Sheep's ancestor (Mouflon)	**6**	**Low Establishment Risk**

3. MERINO SHEEP BREED	**11**	**MODERATE ESTABLISHMENT RISK**
4. DAMARA SHEEP BREED	**6**	**LOW ESTABLISHMENT RISK**
5. DORPER SHEEP BREED	**9**	**MODERATE ESTABLISHMENT RISK**
STAGE C. PEST RISK RANK - RISK OF BECOMING A PEST FOLLOWING ESTABLISHMENT < 9 = low pest risk; 9-14 = moderate pest risk; 15-19 = serious pest risk; > 19 = extreme pest risk	**26**	**EXTREME PEST RISK** Part C was scored using the introduced or feral range of Domestic Sheep (B1), no attempt has been made to distinguish different levels of pest risk for the merino, damara and dorper breeds.
VERTEBRATE PESTS COMMITTEE THREAT CATEGORY (Domestic Sheep – no breeds distinguished)		**EXTREME – ENDORSED BY VPC**
Median number of references per mammal, for all mammals assessed by (Massam et al 2010) (n=17) Total number of references for this species *(median number for references for Public Safety Risk, Establishment Risk and Overseas Environmental and Agricultural Adverse Impacts)*	37 68 – more than the median number of mammal references were used for this assessment, indicating a decreased level of uncertainty.	

Valuable comments concerning domestic sheep breeds were supplied by the external reviewer of this assessment which should be considered in conjunction with the above information in the assessment table:

The use of the distributions of wild progenitors of domestic herbivores like sheep and goats, to predict their distribution and hence risk in Australia is questionable:

Domestication and subsequent selection processes have resulted in sheep and goats that have many preadaptive characteristics that their wild progenitors did not. Therefore, they have such a wide range of pre-adaptive characteristics that are likely to enable survival and establishment in environments dissimilar to their progenitors. This is particularly so for feral goats, which can survive anywhere where the mean annual rainfall is over 225-250 mm.

It is slightly different for sheep, which has been implied in the assessment by selecting the different climatic conditions in the different parts of South Africa for the climate matching.

Four important factors affect the likelihood of sheep becoming feral in Australia;

- whether the sheep retain their fleece or shed it annually,
- their ability to generalise their foraging,
- their behaviour in relation to fences, and
- wild dogs.

These are independent of the climate profile of wild or pre-Macarthur merino progenitors.

Both Damaras and Dorpers shed their fleece, whereas merinos don't. Therefore, fly strike and wool blindness do not occur in the first two breeds.

Merinos with overgrown fleeces are prone to fly strike from a failure of the fleece to dry out after rain in summer as well as permanently wet breeches (in ewes) or bellies (in rams) from urine. Untreated fly strike is usually fatal.

Wool blindness reduces the sheep's ability to forage.

Hence, the Damara and Dorper breeds have an advantage over the Merino breed for these factors.

Using overseas data to predict the distribution of Australian merinos is not useful as since Macarthur's time, the Australian merino has been selected for a number of different environments within Australia, and is very different from mouflon and merinos in other countries.

In addition, there are a number of very different types of Australian merino, e.g. South Australian, Peppin, fine non-Saxon merinos and Saxon types. The Saxon type does better in wetter and colder environments, e.g. Tasmania and the high country along the Great Dividing Range and is hopeless west of the Divide. The South Australian types do well in semi-arid areas and suffer from fly strike in wetter environments, therefore are unlikely to become feral in the distribution shown in your map Climate match 3. It may be worthwhile to review the merino anaysis to reflect the distribution of different merino types within Australia, using the reference Massy C, (2007) The Australian merino: the story of a nation, Random House Australia, North Sydney.

Both Damara and Dorper breeds will survive where even South Australian and Peppin blood merinos starve, probably because of their broader diet (more browse, lower nutrition forage). They seem to be more akin to goats than sheep. This proposition needs analysis, but the hardiness characteristic is an important factor in graziers/ pastoralists choosing them to replace merinos. Both these breeds will escape fences that will contain merinos; and this is already happening in western NSW. Sheep in general do not do well where wild dogs are uncontrolled.
pers.comm. –

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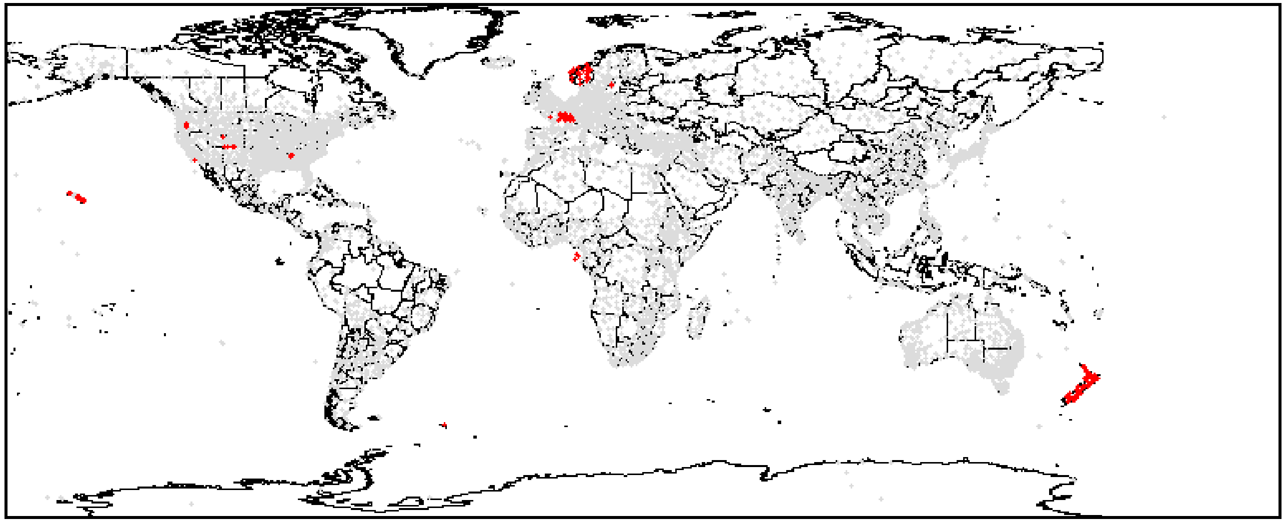
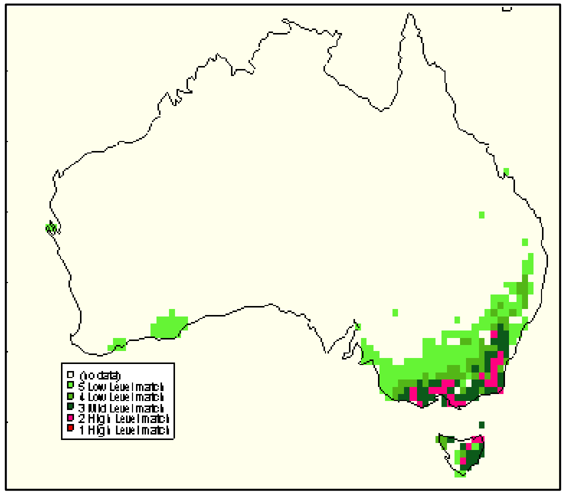
WORLDWIDE DISTRIBUTION Map 1: Domestic Sheep (*Ovis aries*) (No breeds distinguished)

Domestic Sheep have been domesticated for longer than 1000 years and no natural, wild populations occur as defined by the risk assessment model therefore, introduced populations of domestic sheep have been used for the climate analysis. Each red dot is a location where meteorological data was sourced for the climate analysis (see B1), faint grey dots are locations available for CLIMATE analysis but are not within the assessed species' distribution, therefore not used. [Note: CLIMATE data is not available for many of the smaller islands to which sheep have been introduced; therefore, for some of the following introductions the island can not be displayed on the distribution map.]

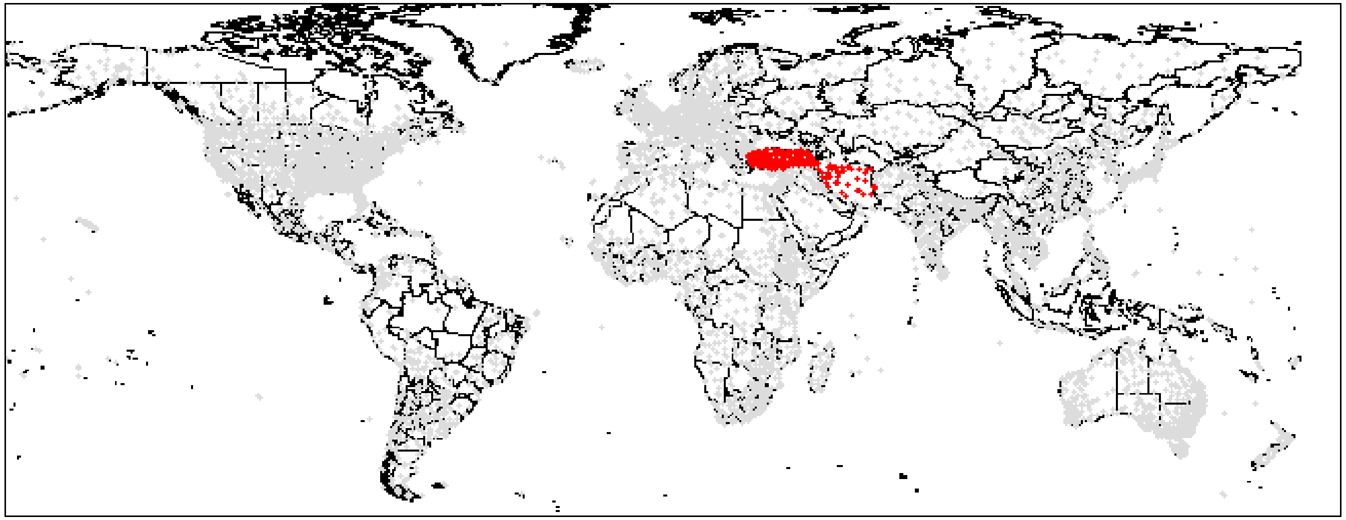


Climate match 1. Between introduced populations overseas of Domestic Sheep (*Ovis aries*) (no breeds distinguished) (distribution Map 1) and Australia for five match classes.

Colour on Map	Level of Match from Highest (10) to Lowest (6)	No. Grid Squares on Map
Red	10 HIGH MATCH	0
Pink	9 HIGH MATCH	26
Dark Green	8 MODERATE MATCH	53
Mid Green	7 MODERATE MATCH	51
Lime Green	6 LOW MATCH	147
		CMS = 277

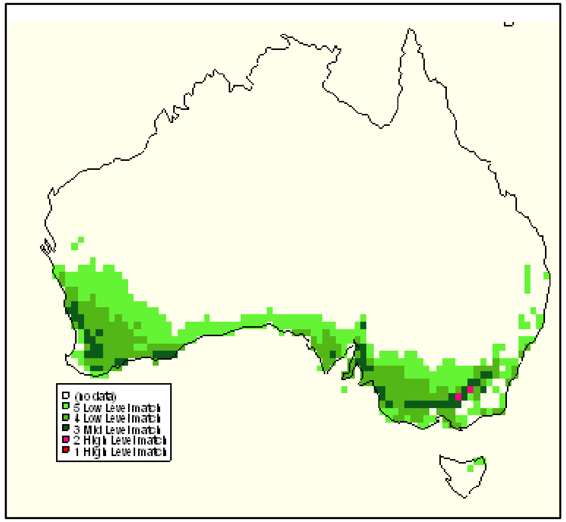


HISTORICAL DISTRIBUTION Map 2: – Domestic Sheep's Ancestor - Asiatic Mouflon (*Ovis orientalis*), 9,000-11,000 years ago, (red dots).

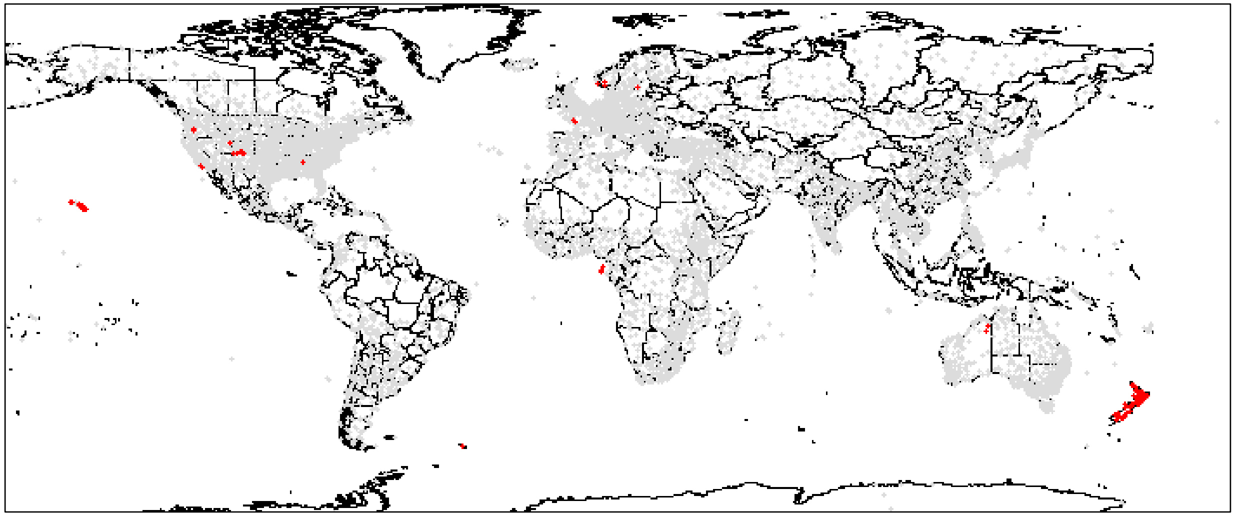


<u>Climate match 2.</u> Using the historical distribution of the **Domestic Sheep's Ancestor -** Asiatic Mouflon (*Ovis orientalis*), (distribution Map 2) and Australia for five match classes

Colour on Map	Level of Match from Highest (10) to Lowest (6)	No. Grid Squares on Map
Red	10 HIGH MATCH	0
Pink	9 HIGH MATCH	2
Dark Green	8 MOD MATCH	53
Mid Green	7 MOD MATCH	178
Lime Green	6 LOW MATCH	264
		CMS = 497

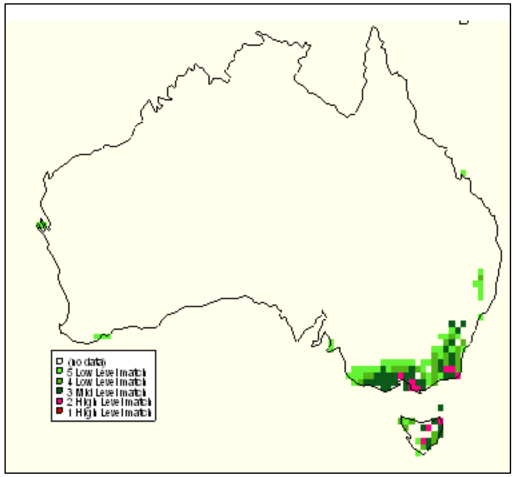


DISTRIBUTION Map 3: – Merino Sheep Breed (*Ovis aries*)
As there is no natural distribution for the Merino Sheep, worldwide introduced populations of Merino (red dots) (excluding populations in Australia) have been used for the climate analysis.

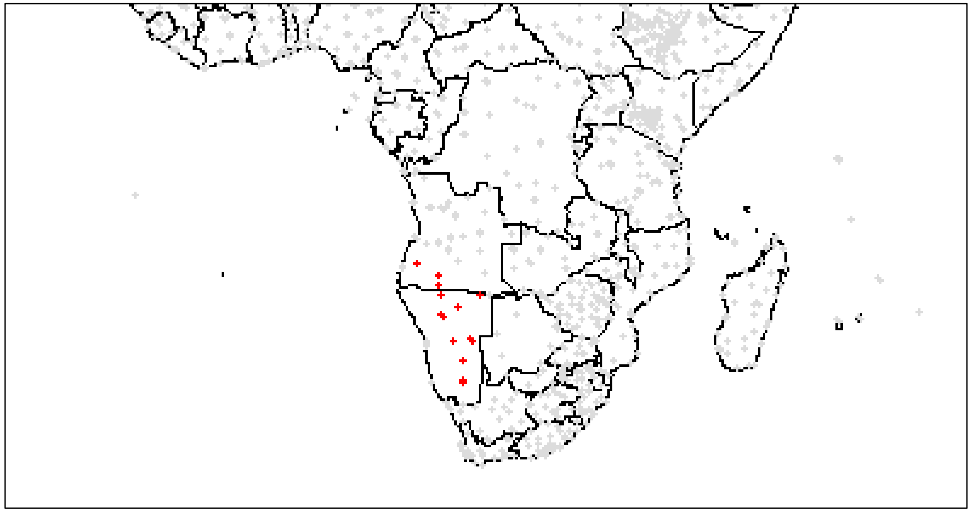


<u>Climate match 3.</u> Between the overseas distribution of introduced populations overseas of Merino Sheep Breed and Australia for five match classes.

Colour on Map	Level of Match from Highest (10) to Lowest (6)	No. Grid Squares on Map
Red	10 HIGH MATCH	0
Pink	9 HIGH MATCH	10
Dark Green	8 MODERATE MATCH	39
Mid Green	7 MODERATE MATCH	29
Lime Green	6 LOW MATCH	48
		CMS = 126

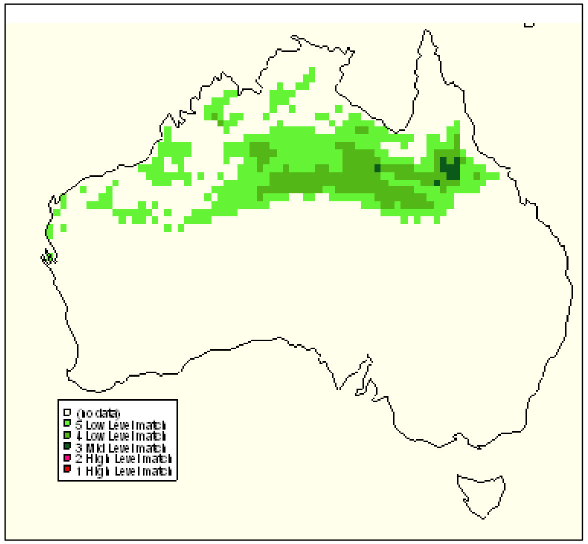


DISTRIBUTION Map 4: – Damara Sheep Breed (*Ovis aries*), area of South Africa where the breed was developed. No breed-specific information regarding introduced Damara populations, so areas of South Africa where the breed was developed (distribution Map 4), have been used for the climate analysis.

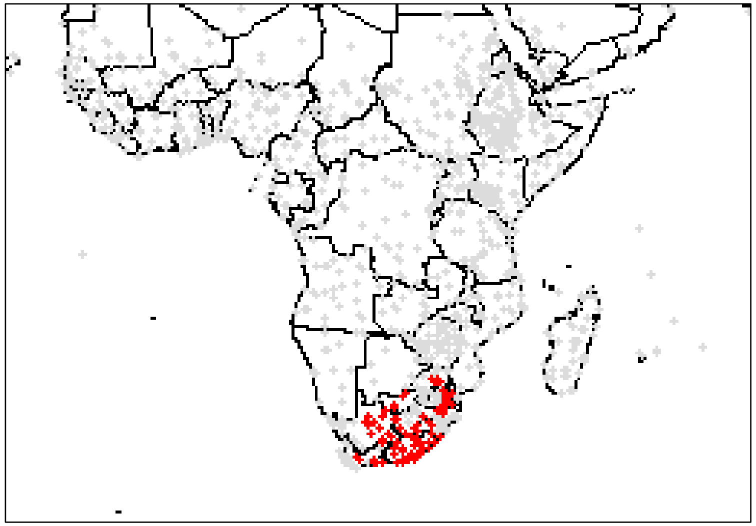


<u>Climate match </u>4. Between the area of South Africa where the Damara Sheep Breed was developed and Australia for five match classes. No breed-specific information regarding introduced Damara populations, so areas of South Africa where the breed was developed (distribution Map 4), have been used for the climate analysis.

Colour on Map	Level of Match from Highest (10) to Lowest (6)	No. Grid Squares on Map
Red	10 HIGH MATCH	0
Pink	9 HIGH MATCH	0
Dark Green	8 MODERATE MATCH	9
Mid Green	7 MODERATE MATCH	139
Lime Green	6 LOW MATCH	345
		CMS = 493

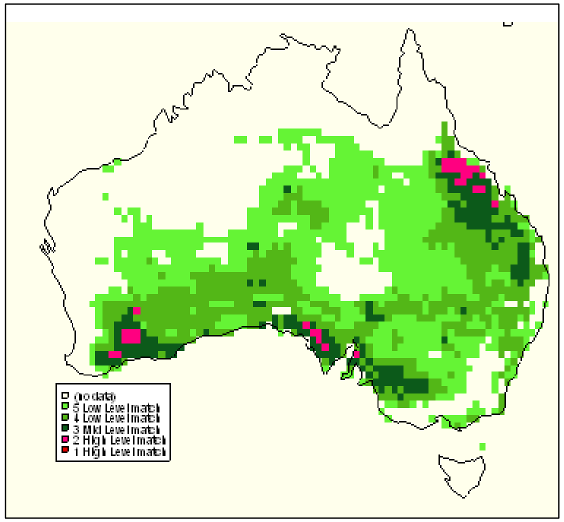


DISTRIBUTION Map 5: – Dorper Sheep Breed (*Ovis aries*), area of South Africa where the breed was developed. No breed-specific information available, areas in South Africa where the breed was developed (distribution Map 5), have been used.

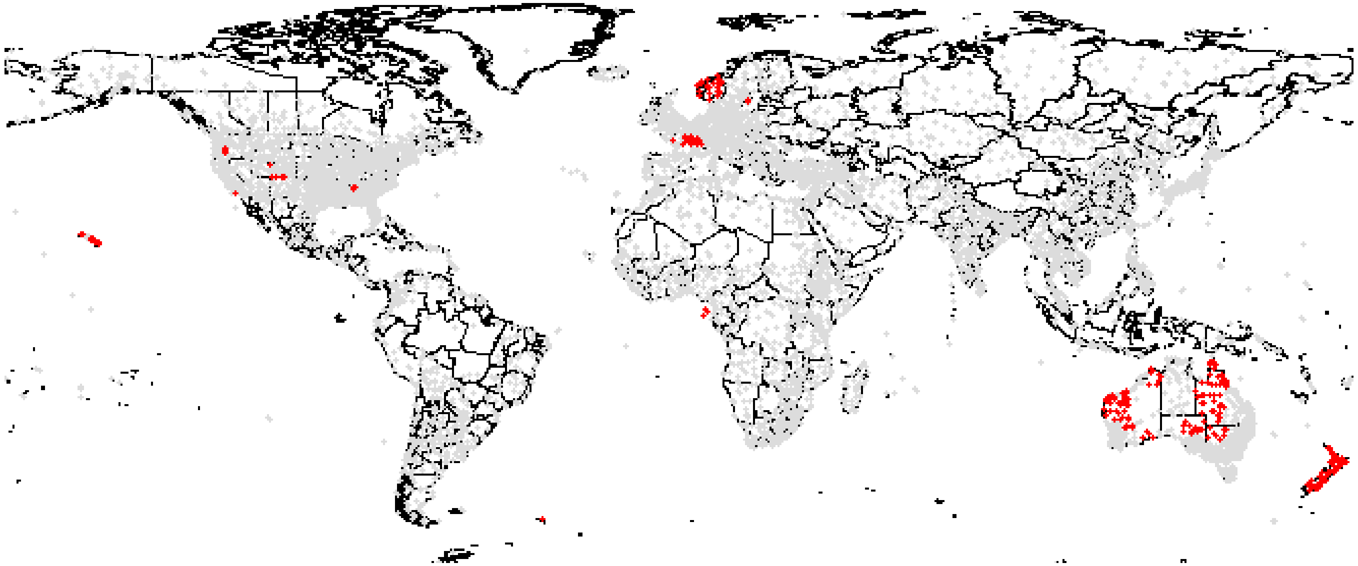


<u>Climate match 5.</u> Between the area of South Africa where the Dorper Sheep Breed was developed and Australia for five match classes.

Colour on Map	Level of Match from Highest (10) to Lowest (6)	No. Grid Squares on Map
Red	10 HIGH MATCH	0
Pink	9 HIGH MATCH	33
Dark Green	8 MODERATE MATCH	179
Mid Green	7 MODERATE MATCH	558
Lime Green	6 LOW MATCH	840
		CMS = 1610

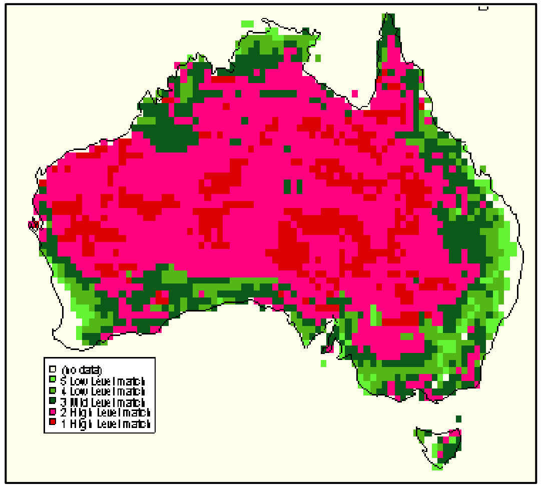


DISTRIBUTION Map 6: – Additional analysis, for interest in predicting suitable areas in Australia The worldwide distribution of introduced populations of Domestic Sheep (no breed distinguished) including Australian feral populations.



<u>Climate Match 6.</u> Additional analysis, for interest in predicting suitable areas in Australia for feral populations to establish. The worldwide distribution of introduced populations of Domestic Sheep (no breed distinguished) including Australian feral populations (118 locations used for the climate analysis).

Colour on Map	Level of Match from Highest (10) to Lowest (6)	No. Grid Squares on Map
Red	10 HIGH MATCH	435
Pink	9 HIGH MATCH	1389
Dark Green	8 MOD MATCH	519
Mid Green	7 MOD MATCH	265
Lime Green	6 LOW MATCH	101
		CMS = 1309



Domestic Sheep (*Ovis aries*) (no breed distinguished) Susceptible Australian Primary Production – Calculating Total Commodity Damage Score

The commodity value index scores in this table are derived from Australian Bureau of Statistics 2005 – 2006 data. The values will require updating if significant change has occurred in the value of the commodity (Bomford 2008).

Table 9

Industry	**Commodity Value Index (based on 1999 - 2000 data)**	**Potential Commodity Impact Score (0-3)**	**Climate Match to Commodity Score (0–5)**	**Commodity Damage Score (columns 2 X 3 X 4)**
Cattle (includes dairy and beef) consumption of stock fodder consumption of stock fodder only therefore commodity value adjusted down by 1/3	**11**	**2**	**4**	**88**
Timber (includes native and plantation forests)	**10**	**2**	**3**	**60**
Cereal grain (includes wheat, barley sorghum etc) no reports of damage to this commodity	**8**	**2**	**4**	**64**
Sheep (includes wool and sheep meat) consumption of stock fodder only therefore commodity value adjusted down by 1/3	**5**	**2**	**4**	**40**
Fruit (includes wine grapes)	4	0	0	0
Vegetables	3	0	0	0
Poultry and eggs	2	0	0	0
Aquaculture(includes coastal mariculture)	2	0	0	0
Oilseeds (includes canola, sunflower etc) no reports of damage to this commodity	**1**	**2**	**4**	**8**
Grain legumes (includes soybeans) no reports of damage to this commodity	**1**	**2**	**4**	**8**
Sugarcane	1	0	0	0
Cotton	1	0	0	0
Other crops and horticulture (includes nuts tobacco and flowers etc)	**1**	**2**	**4**	**8**
Pigs	1	0	0	0
Other livestock (includes goats, deer, camels, rabbits)	**0.5**	**2**	**3**	**3**
Bees (included honey, beeswax and pollination)	**0.5**	**2**	**5**	**0**
Total Commodity Damage Score (TCDS)				**279.0**

[Table 9 Rational
Potential Commodity Impact Score (0-3)
Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9, and pest status worldwide as:

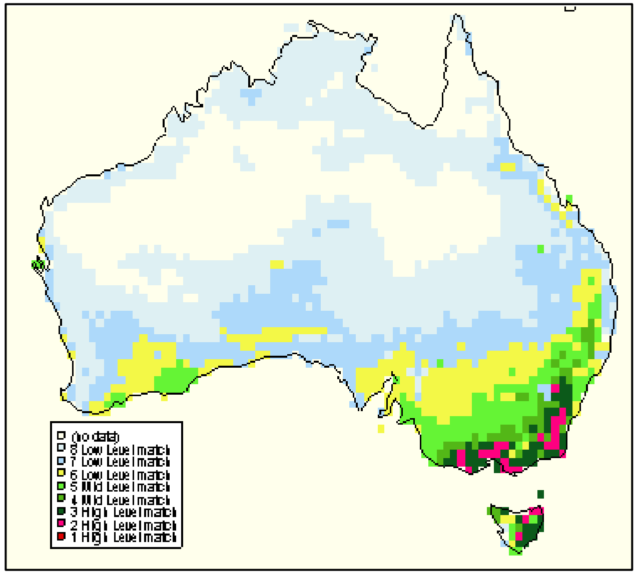
0. *Nil (species does not have attributes to make it capable of damaging this commodity)*
1. *Low (species has attributes making it capable of damaging this or similar commodities and has had the opportunity but no reports or other evidence that it has caused damage in any country or region*
2. *Moderate–serious (reports of damage to this or similar commodities exist but damage levels have never been high in any country or region and no major control programs against the species have ever been conducted OR the species has attributes making it capable of damaging this or similar commodities but has not had the opportunity)*
3. *Extreme (damage occurs at high levels to this or similar commodities and/or major control programs have been conducted against the species in any country or region and the listed commodity would be vulnerable to the type of harm this species can cause).*

Climate Match to Commodity Score (0–5)

- *None of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes (ie classes 10, 9, 8, 7, 6, 5, 4 and 3) = 0*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes = 1*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes (ie classes 10, 9, 8, 7, 6 and 5) = 2*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes AND less than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes (ie classes 10, 9 and 8) = 3*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT more than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *OR More than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT less than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *More than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes OR overseas range unknown and climate match to Australia unknown = 5.]*

Climate Match - Between the overseas distribution of introduced Domestic Sheep (*Ovis aries*) (no breeds distinguished) (distribution Map 1, excluding Australian distribution) and Australia for eight match classes.

Colour on Map	Level of Match from Highest (10) to Lowest (3)	No. Grid Squares on Map
Red	10 HIGH MATCH	0
Pink	9 HIGH MATCH	26
Dark Green	8 HIGH MATCH	53
Mid Green	7 MOD MATCH	51
Lime Green	6 MOD MATCH	147
Yellow	5 MOD MATCH	256
Blue	4 LOW MATCH	464
Light blue	3 LOW MATCH	1039



Appendix 1 – Additional information sheep zoonoses and harm to humans

[Information on zoonoses obtained from: (Stevenson and Hughes 1988)].

Cryptosporidiosis – caused by the protozoan *Cryptosporidium* spp. Faecal-oral transmission through direct contact with animals, indirect spread by contaminated food or water. Symptoms include abdominal cramps, diarrhoea, nausea and vomiting. The illness is more severe in immunocompromised persons, and may end in death. People at risk may include backpackers, hikers, and campers who drink unfiltered, untreated water, including swimmers, who swallow water from contaminated sources.

Q-Fever – Virus caused by the agent *Coxiella burnetti*. The most common means of transmission is by inhalation of aerosols or dust contaminated with *Coxiella* from infected ruminants; also by contact with infected animals and contaminated articles such as straw and wool. It is essentially an occupational disease, mainly in the meat industry. Rarely direct person-to-person transmission. Usually the onset is acute, characterised by chills, fever, sweating, headache; possibly couch, nausea and vomiting. Mild rashes occur in a minority for 2-5 days. Serious chronic complications are uncommon; endocarditis causes the most concern, and may be diagnosed months or up to many years after the acute illness. The overall mortality is low, probably 1% or less in untreated cases.

Fascioliasis – caused by *Fasciola hepatica* (sheep liver fluke). People can be infected by eating vegetation (particularly watercress) or drinking water containing cysts. Reports of cases are rare, and there is no direct person-to-person transmission. The adult fluke causes liver pain and tenderness, possibly rigidity of the abdominal wall, and diarrhoea.

Trichostrongylidiosis – caused by the nematode *Trichostrongylus* spp. Transmission is by ingestion of vegetation contaminated with the larvae. Cases are rare. Infections are usually light and asymptomatic. Heavy infections may result in abdominal pain, diarrhoea and anaemia. Occasional fatalities have been reported overseas.

Salmonella – caused by the bacilli *Salmonella*, this disease is present in a wide range of domestic livestock, wild animals and pets. Transmission is usually by ingestion of contaminated materials. Salmonella is essentially a gastrointestinal illness with abrupt onset. Symptoms include nausea, abdominal pain and vomiting. High-risk groups include persons eating unhygienically-prepared, stored or handled food.

Dermatophilosis – caused by the bacterium *Dermatophilus congolensis*. Transmission is usually via contact with infected animals, particularly wet sheep, as wet weather encourages release of the infecting zoospores. Reported transmission to humans is rare, and there is no evidence of person-to-person transmission. An erythematous rash appears on the skin in contact with the animal. Multiple discrete painless pustules 2-5 m diameter develop. Scabs form, which remain active for up to two weeks before being shed leaving a reddish-purple scar. This is a relatively mild infection.

Pasteurellosis – caused by the coccobacilli *Pasteurella multocida and P. haemolytica*. Transmission is via inhalation (*P. multocida*) by people in close contact with animals, or infection of wounds (*P. haemolytica*). A variety of symptoms may follow exposure to *P. multocida*, including pneumonitis, pneumonia, meningitis, brain abcess, cyctitis, and appendicitis. Many cases have occurred in immunocompromised persons. Symptoms of infection by *P. haemolytica* include local papules, lymphadenitis, lympangitis, and low grade fever

Orf – viral disease. Transmission usually by skin contact with an infected animal. It is essentially an occupational disease among persons handling sheep and sheep products. The disease is not commonly reported considering the prevalence in sheep. Lesions are found on the hands, fingers and forearms, occasionally on the face and other parts of the body. Over the ensuing 2 weeks, an ulcer forms, taking 4-6 weeks to heal. There is no specific treatment and measures are directed at preventing secondary bacterial infection.

Myiasis – caused by the larvae of *Oestris ovis* (sheep nasal bot-fly). Man is infected by the female fly ejecting up to 50 larvae into the eye by aerial transmission. Only occasionally reported, the disease affects sheep stockmen, drovers and shearers. Symptoms include severe eye irritation. Penetration of the deep tissues and associated serious complications have not been reported in Australia.

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Vertebrate Pests Committee Threat Categories (Natural Resource Management Standing Committee 2004).

VPC Threat Category

A species' VPC Threat Category is determined from the various combinations of its three risk ranks; (A) Public safety risk rank, (B) Establishment risk rank, (C) Pest risk rank.

B. Establishment Risk Rank[1]	C. Pest Risk Rank[1]	A. Public Safety Risk Rank	Threat Category
Extreme	Extreme	Highly Dangerous, Moderately Dangerous or Not Dangerous	**Extreme**
Extreme	High	Highly Dangerous, Moderately Dangerous or Not Dangerous	**Extreme**
Extreme	Moderate	Highly Dangerous, Moderately Dangerous or Not Dangerous	**Extreme**
Extreme	Low	Highly Dangerous, Moderately Dangerous or Not Dangerous	**Extreme**
High	Extreme	Highly Dangerous, Moderately Dangerous or Not Dangerous	**Extreme**
High	High	Highly Dangerous, Moderately Dangerous or Not Dangerous	**Extreme**
High	Moderate	Highly Dangerous, Moderately Dangerous or Not Dangerous	**Serious**
High	Low	Highly Dangerous, Moderately Dangerous or Not Dangerous	**Serious**
Moderate	Extreme	Highly Dangerous, Moderately Dangerous or Not Dangerous	**Extreme**
Moderate	High	Highly Dangerous, Moderately Dangerous or Not Dangerous	**Serious**
Moderate	Moderate	Highly Dangerous	**Serious**
Moderate	Moderate	Moderately Dangerous or Not Dangerous	**Moderate**
Moderate	Low	Highly Dangerous	**Serious**
Moderate	Low	Moderately Dangerous or Not Dangerous	**Moderate**
Low	Extreme	Highly Dangerous, Moderately Dangerous or Not Dangerous	**Serious**
Low	High	Highly Dangerous, Moderately Dangerous or Not Dangerous	**Serious**
Low	Moderate	Highly Dangerous	**Serious**
Low	Moderate	Moderately Dangerous or Not Dangerous	**Moderate**
Low	Low	Highly Dangerous	**Serious**
Low	Low	Moderately Dangerous	**Moderate**
Low	Low	Not Dangerous	**Low**

[1] 'Establishment Risk' is referred to as the 'Establishment Likelihood' and 'Pest Risk' is referred to as the 'Establishment Consequences' by the Natural Resource Management Standing Committee (2004).