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REPORT ON THE OPEN-ENDED INTERSESSIONAL CONTACT GROUP ON DISEASES OF ANTARCTIC WILDLIFE

REPORT 1 – REVIEW AND RISK ASSESSMENT

Report on the open-ended intersessional contact group on diseases of Antarctic wildlife
Report 1 – Review and risk assessment

Background

CEP III agreed to the following terms of reference for the open-ended intersessional contact group (ICG) on diseases of Antarctic wildlife:

That the contact group prepare an initial report for CEP IV which:

- ***provides a review of the introduction and spread by human activity of infectious disease causing agents in Antarctica and provides a risk assessment of those activities which may introduce or spread disease causing agents in Antarctica;***
- *presents practical measures that might be implemented by Parties to diminish the risk to Antarctic wildlife of the introduction and spread by human activity of infectious disease causing agents; and*
- *presents practical measures that may be implemented to determine the cause of unusual wildlife mortality and morbidity events in Antarctica and to reduce the likelihood that human activity may exacerbate these events.*

(CEP III Report Paragraph 52)

This paper reports on the work of the ICG in response to the first of the terms of reference. The ICG's report is at Annex 1. Australia coordinated the process, with participation from AEON, ASOC, IAATO, Italy, Norway and Sweden.

The review and risk assessment were used by the ICG to identify those human activities that are a priority for practical measures to diminish the risk to Antarctic wildlife from the introduction and spread by human activity of infectious disease causing agents. The ICG seeks CEP endorsement of the list of activities identified as priorities and will then complete work on practical measures to diminish risk.

A draft report prepared by the ICG in response to the second of the terms of reference on practical measures is submitted as an annex to a separate working paper. The ICG does not yet have a draft report in response to the third of the terms of reference.

Outcome of review and risk assessment

The ICG reached a number of conclusions on the basis of the review and risk assessment.

Risk assessment methodology

1. There is insufficient information available to conduct a reliable quantitative risk assessment of disease introduction and spread to Antarctic wildlife.
2. A qualitative risk assessment approach should be sufficient to indicate priorities for precautionary measures.

Historic information on disease

3. No diseases have been demonstrated to have been introduced to Antarctic wildlife or spread by human activities.
4. No systematic studies of disease in Antarctica have been undertaken and it is unlikely that conclusive evidence of human involvement in disease events would be available.

5. There is recent evidence to indicate that some microorganisms have been introduced to Antarctic wildlife and spread as a consequence of human activity.
6. Seven unusual mortality events in which disease was suspected have been recorded for Antarctic wildlife. Only one was investigated and the causes of the others are not known.
7. A seal mass mortality event on the Auckland Islands in 1998 was well investigated but the causal agent is still not known with certainty, indicating that identification of the cause of a mortality event is not always possible.
8. Clinical and serological evidence indicates that many Antarctic and sub-Antarctic penguins and seals have been exposed to infectious disease causing agents, indicating that they are not completely naïve populations with respect to disease.
9. Captive Antarctic birds and seals have exhibited symptoms of a variety of diseases known in other wildlife populations, indicating that they are susceptible to a range of diseases.
10. Disease is suspected in a significant number of the marine mammal mass mortality events reported in non-Antarctic regions.
11. Most of the diseases on the Office International des Epizooties (OIE), the world organisation for animal health, List A of transmissible diseases with the potential for very serious and rapid spread occur in countries that participate in Antarctic activities. This indicates that, despite the economic incentives to prevent them and the large preventive effort, serious transmissible diseases of animals occur in most countries.
12. Most OIE List A diseases would not be transmissible to birds and seals, however, there is evidence that birds and seals are susceptible to some, such as Newcastle disease and avian influenza.
13. Newcastle disease has occurred widely in ATCP countries in recent years and may be the disease most likely to be a risk to Antarctic wildlife.
14. Diseases most likely to be of risk of introduction and spread by people are those that are established in the home countries of people visiting Antarctica, can survive well without a host, do not require a vector that is not present and can infect different hosts, examples include Newcastle disease, avian influenza and the morbilliviruses causing canine and phocine distemper.
15. It is not possible to identify all diseases with the potential for introduction and this is not necessary as a precursor to implementation of precautions.

Factors that could influence disease introduction or spread

16. Environmental conditions in parts of the Antarctic are similar to conditions elsewhere and so mechanisms for disease transfer that occur in these places are likely to also occur in Antarctica.
17. The cold and lack of available water may make otherwise simple precautions difficult or impossible under some circumstances such as at remote field locations.
18. Animal behaviour will influence the likelihood of disease transmission within populations and between species.
19. Several Antarctic species migrate beyond the Antarctic to regions where they could be in contact with disease causing agents carried by other wildlife and in human waste at sewage effluent outfalls and waste disposal tips.
20. Carrion feeders are most likely to be in direct contact with diseased or dying animals of other species.
21. Opportunist scavengers are most likely to feed on waste generated by human activity if precautions are not taken to prevent access.
22. Skuas are among the most likely species to be the point of entry of disease from waste because they are not shy of people and they will scavenge on station waste given the

opportunity. They are also among the most likely routes of transfer to other species because of their habit of associating with other species.

Human activities which may introduce or spread disease

23. Activities undertaken before going to Antarctica, including precautions, will determine whether people bring infectious disease with them.
24. Activities in Antarctica most likely to cause disease introduction or spread are those that involve close contact with wildlife or those that allow wildlife to come in contact with waste generated from human activities.
25. Certain combinations of activities may significantly increase the risks.
26. Precautions should be prioritised to target the most likely pathways of disease introduction or spread.
27. Human activities identified as priorities for practical measures to diminish risk are,
    - Feeding of wildlife
    - Actions following discovery of unusual mortality events
    - Research that involves handling of Antarctic animals, particularly research on disease
    - Import of food, particularly poultry products
    - Waste disposal and sewage treatment
    - Use of equipment and clothing before departure to Antarctica
    - Serial visits to wildlife aggregations

Recommendations

It is recommended that:

- the CEP accepts the attached report (Annex 1) from the ICG in fulfilment of the requirement to provide CEP with a review of the introduction and spread by human activity of infectious disease causing agents in Antarctica and to provide a risk assessment of those activities which may introduce or spread disease causing agents in Antarctica
- the CEP notes the conclusions of the ICG
- the CEP considers the list of human activities identified by the ICG as priorities for practical measures to diminish risk and, if appropriate, endorses these as the basis for further work by the ICG on practical measures to diminish the risk to Antarctic wildlife of the introduction and spread by human activity of infectious disease causing agents
- the CEP encourages Parties, COMNAP, SCAR, CCAMLR and other expert bodies such as IUCN to nominate relevant specialists to participate in the continued work of the open-ended contact group.

ANNEX 1

REVIEW OF THE INTRODUCTION AND SPREAD BY HUMAN ACTIVITY OF INFECTIOUS DISEASE CAUSING AGENTS AND RISK ASSESSMENT OF THOSE ACTIVITIES WHICH MAY INTRODUCE OR SPREAD DISEASE CAUSING AGENTS IN ANTARCTICA

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1 METHODOLOGY FOR REVIEW AND RISK ASSESSMENT

The review and risk assessment process included the following steps,

1. agreement on the risk assessment approach to be used (a discussion of the risk assessment procedure used is included as Attachment 1);
2. review of historic information on wildlife diseases in Antarctica and elsewhere to determine if particular diseases should be a concern, including,
    a. diseases known to have been introduced to Antarctic wildlife or spread by human activity
    b. documented wildlife mass mortality events in Antarctica and the subantarctic
    c. indications that Antarctic and sub-Antarctic wildlife have been exposed to infectious disease causing agents
    d. diseases considered a risk to wildlife in other regions
    e. characteristics of disease that influence their risk
3. assessment of characteristics of the Antarctic environment and biota to determine,
    a. whether there are particular characteristics that increase the chance of disease introduction,
    b. whether particular species are at greater risk;
4. assessment of human activities to determine whether there are particular activities that have an increased chance of causing introduction or spread of disease.
5. identification of combinations of activities (scenarios) that increase risk

2 DISEASES THAT MAY BE A RISK TO ANTARCTIC WILDLIFE

2.1 Diseases known to have been introduced to Antarctic wildlife or spread by human activity

No diseases have been demonstrated to have been introduced to Antarctic wildlife or spread among them as a consequence of human activity. The epidemiology of disease in Antarctic wildlife has been little studied and on the basis of information currently available, it is unlikely that past disease events could have been attributed unequivocally to the activities of people. To date there have been no concerted studies designed to determine the origin of disease agents in Antarctic wildlife or their mode of introduction. Recent evidence indicates that some microorganisms have been introduced to Antarctic wildlife and spread as a consequence of human activity (Broman *et al* 2000, Palmgren *et al* 2000).

In other regions of the world significant resources are directed towards determining the cause of disease outbreaks, often without success. However, despite the lack of direct proof of human involvement in many disease events, humans are recognised as potential disease vectors and appropriate precautions are taken. The absence of evidence for the past involvement of people in disease introduction in Antarctica is not evidence that people have not been involved or that they could not be involved in future.

2.2 Documented wildlife mass mortality events in Antarctica and the subantarctic

Disease has been suspected in six recorded unusual mortality events of birds and one of seals in the Antarctic Treaty area. There have been few cases where a disease has been expressed and the cause identified. An exception is the case of avian cholera, *Pasteurella multocida* (strain 1-X73), in which four pairs of the brown skua, *Catharacta lonnbergi*, died suddenly on Livingston Island (Parmelee, 1979). The disease has also been observed on more than one occasion on sub-Antarctic Campbell Island where *P. multocida* has been isolated from dead rockhopper penguins (de Lisle et al, 1990). A 90% mortality of banded brown skuas at Admiralty Bay on King George Island in 1981 was reported as being similar to the mortality on Livingston Island (Trivelpiece *et al,* 1981) but no evidence for cause was reported.

38 adult subantarctic skuas, *Catharacta antarctica,* were found dead at Hope Bay on the Antarctic Peninsula in 1990 (Montalti *et al*, 1996). The animals showed no unusual pathological signs but no analyses for disease agents were undertaken.

37 sheathbills, *Chionis alba,* were found dead in the vicinity of Factory Cove on Signey Island between July and October 1965 (Howie et al 1968). Bacteriological, histological and parasitological examinations of three carcasses were negative. Extreme weather conditions could have contributed to some of the deaths and poisoning from chemical waste from a station was also suggested as a possible cause.

Several hundred gentoo penguin chicks were found dead on Signy Island, Antarctica (MacDonald and Conroy, 1971). The symptoms were described as similar to the viral disease puffinosis that occurs in Manx shearwaters (*Puffinus puffinus*). Body condition appeared to be good, however, all had multiple ulcers, 2-4 mm in diameter, on the dorsal surfaces of their feet. Many were found lying face down and those that were still alive were unable to stand unaided. The causal agent was not identified. Adélie and chinstrap penguins in adjacent colonies were not affected.

Large numbers of plump and apparently well-nourished Adélie penguin chicks were found dead and dying at Low Tongue approximately 40 km west of Mawson in February 1972 (Kerry et al, 1996). 65% of chicks had died recently and many of those still alive were found face down and could not stand on their own. The cause of death was not investigated at the time and remains unknown.

At least 1500 crabeater seals, *Lobodon carcinophagus,* were found dead in the Crown Prince Gustav Channel, Antarctic Peninsula in 1955 (Laws and Taylor, 1957). All affected seals had swollen necks and blood running from their mouths, on dissection their guts were empty, their livers pallid and pus oozed from the neck glands when incised (Fuchs, 1982). The cause was suspected to be a highly contagious virus possibly exacerbated by stress from crowding and partial starvation as a result of being trapped by ice. The cause of death was not investigated and remains unknown.

A mass mortality of New Zealand sea lions, *Phocarctos hookeri,* on the New Zealand sub-Antarctic Auckland Islands, in January-February 1998 (Gales and Childerhouse, 1999) is better documented than any of the events that occurred in the Antarctic. About 1600 pups and an unrecorded number of adults died. At the start of the event dead pups were in good condition (plenty of fat) but as the event progressed more lean and apparently starving pups were found. Pups had few clinical signs of disease although some showed paralysis in the hind limbs that appeared to be associated with an abscess. Other clinical signs were noted but these could have been secondary. The most common symptom of the adults was swelling in the throat region that appeared to be caused by an extensive abscess in the tissue surrounding the salivary gland. Some animals also had a number of raised swellings, about 1 cm in diameter in the ventral region of the body. A few adults were apparently paralysed in the hind limbs as seen in the pups. Animals were autopsied and samples of tissue, serum, milk and faeces were collected. Examination included gross pathology, histopathology, virology, serology, parasitology and chemical analysis for organochlorine pesticides. Other investigations included analysis for algal biotoxins and documentation of oceanographic conditions. A previously unidentified bacterium (Campylobacter like) is thought to have been the primary pathogenic agent, however, despite the thorough investigation, the cause remains uncertain. This illustrates the difficulty in identifying causal agents for mass mortalities.

These events indicate that mass mortalities occur in Antarctic and sub-Antarctic wildlife and that unless samples are collected during or soon after the event there is very little likelihood of identifying the causal agent. The experience on the Auckland Islands demonstrates that even after intense sampling and investigation by skilled people with appropriate expertise the causative agent may not be identified. If the causative agent is not known it is not likely that humans could be implicated or disregarded with confidence as agents of introduction or spread of the causative agent.

2.3 Indications that Antarctic and sub-Antarctic wildlife have been exposed to infectious disease causing agents

Evidence from clinical examination, pathology and serology indicates that Antarctic and sub-Antarctic wildlife have been exposed to a variety of infectious disease causing agents in the past (Table 1). Much of the evidence is based on antibody reactions and in most cases there were no clinical signs of disease. Serological evidence, such as anti-body reactions, is not conclusive proof of past exposure to infectious disease causing agents. To confirm the presence of a disease causing agent it must be isolated, however, isolation of an agent does not prove that it has caused disease.

Serological evidence (Table 1) indicates that Antarctic wildlife have been exposed to a variety of agents that cause antibody reactions that are the same as, or similar to, those caused by known infectious disease causing agents. The presence of antibodies also indicates that these species have active immune systems and have survived exposure to these agents.

There are no published accounts of systematic studies designed to determine whether humans have been involved in the introduction or spread of infectious disease causing agents to Antarctica. As a consequence, there is no conclusive evidence that human activity has or has not been responsible for the introduction to the Antarctic region of the agents causing the antibody reactions or the pathological or clinical signs observed in Antarctic wildlife.

Table 1. Evidence for exposure of Antarctic and sub-Antarctic birds and mammals to infectious disease causing agents (based on Clark and Kerry, 2000 and other sources)

Disease causing agent and associated disease	Host species and location	Type of evidence	Reference
Bacteria and fungi			
Borrelia burgdorferi sensu lato (Lyme disease)	King penguins (Crozet)	Antibodies	Gauthier-Clerc et al 1999
Salmonella *Salmonella enteritidis* *Salmonella enteritidis*	Adélie penguins (Ross Island) and south polar skuas Gentoo penguins (Bird Island) Fur seals, black browed albatross, gentoo penguins	Isolated Isolated Isolated	Oelke and Steiniger 1973 Olsen *et al* 1996 Palmgren *et al* 2000
Chlamydia sp *Chlamydia psittaci*	Emperor penguin (Auster) and rockhopper, royal and gentoo penguins (Macquarie Island) Brown skua	Antibodies DNA detection	Moore and Cameron 1969, Cameron 1968 Herman *et al* 2000
Pastuerella multocida (avian cholera)	Rockhopper penguins (Campbell Island) Brown skua (Palmer)	Isolated Mortality, agent isolated	Lisle *et al* 1990 Parmelee *et al* 1978
Brucella sp (brucellosis)	Weddell and fur seals	Antibodies	Retamal *et al* 2000, Blank *et al* 2000
Campylobacter jejuni	Birds and seals (South Georgia)	Isolated	Broman *et al* 2000
Mycobacteria (tuberculosis)	Fur seal	Pathology, isolated	Bastida *et al* 1999
Viruses			
Avian paramyxovirus (Newcastle disease) Non-pathogenic paramyxovirus strains	Adélie and royal penguins Royal and king penguins Adélie penguins	Antibodies Isolated Antibodies	Morgan *et al* 1978, Morgan and Westbury 1988 Morgan and Westbury 1981
Avian influenza (influenza A)	Adélie penguins (Casey) Adélie penguins and Antarctic skuas (Ross Sea)	Antibodies Antibodies	Morgan and Westbury 1981 Austin and Webster 1993
Flaviviruses	Various penguins (sub-Antarctic)	Antibodies	Morgan *et al* 1985
Birnavirus (infectious bursal disease virus or Gumboro disease)	Shearwaters, Adélie and emperor penguins	Antibodies	Gardner *et al* 1997
Avian adenovirus	Rockhopper penguins	Antibodies	Karesh 1999
Avian encephalomyelitis virus	Rockhopper penguins	Antibodies	Karesh 1999
Coronavirus (infectious bronchitis virus)	Rockhopper penguins	Antibodies	Karesh 1999
Avian reovirus	Rockhopper penguins	Antibodies	Karesh 1999
Unknown virus (puffinosis)	Gentoo penguins (Signy Island)	Clinical signs similar to those	MacDonald and Conroy 1971

		of puffinosis	
Morbilliviruses Canine distemper virus	Leopard and crabeater seals (Antarctic Peninsula)	Antibodies	Bengtson and Boveng 1991
Herpesviruses European phocine herpesvirus Phocine herpesvirus	Weddell and crabeater seals (Weddell Sea) Weddell seal	Clinical signs of respiratory disease and antibodies to herpesvirus Antibodies	Harder *et al* 1991 Stenvers et al., 1992

The occurrence of disease among captive representatives of Antarctic species (Table 2) indicates that, under certain conditions, these animals are susceptible to, and will express the symptoms of, diseases known from non-Antarctic regions.

Table 2. Evidence of infectious disease in captive Antarctic birds and mammals

Disease causing agent (and associated disease)	Host species	Evidence	Reference
Protozoa			
Plasmodium (avian malaria)	Penguins King penguin	Histopathology Clinical signs, agent isolated	Stoskopf and Beier 1979 Penrith *et al* 1996
Coccidia (coccidiosis)	Common seals	Clinical signs, histopathology, agent isolated	Munro and Synge 1991
Bacteria and fungi			
Salmonella	Penguins		Cockburn 1947
Pa*stuerella multocida* (avian cholera)	Unspecified seals		Lynch 1999
Non-specific bacterial infection (bumblefoot)	Penguins	Clinical signs	Gailey-Phipps 1978, Stoskopf and Beall 1980
Clostridium perfringens	King Penguins Gentoo penguins	Clinical signs, agent isolated Clinical signs, agent isolated	Penrith *et al* 1996 Fielding 2000
Aspergillus (aspergillosis)	Penguins Gentoo penguins	Presence of spores Clinical signs, agent isolated	Stoskopf and Beall 1980 Fielding 2000, Flach *et al* 1990
Viruses			
Avian paramyxovirus (Newcastle Disease)	Adélie penguin King penguins	Clinical signs of Newcastle disease Isolated	Pierson and Pfow 1975 Krauss *et al* 1963
Herpesvirus-like	Blackfooted penguins	Clinical signs, isolated and electron microscopy	Kincaid *et al* 1988

2.4 Diseases considered a risk to wildlife in other regions

There is an enormous literature reporting diseases and the occurrence of infectious disease causing agents among wild stocks of non-Antarctic species of seals and penguins and other sea mammals and sea-birds. It is not possible or necessary to undertake a complete review of this literature. Examples are provided to illustrate the range of diseases reported on the basis of clinical signs, pathology and antibody reactions (Table 3). Clearly elsewhere in the world many diseases are circulating actively among birds and marine mammals.

Table 3. Evidence of infectious disease in wild stocks of non-Antarctic seals, and penguin and other marine mammals and sea-birds.

Disease causing agent (and associated disease)	Host species	Evidence	Reference
Ectoparasites			
Nasal mites	Young fur seals	Presence	Kim et al 1980
Endoparasitic Worms			
Nematodes - gastric	Seals	Presence	Baker 1987, Baker 1989
Nematodes - hookworm	Seals	Presence	Abegglen *et al* 1958, George-Nascimento *et al* 1992, Lyons et al 1997
Nematodes – lungworm Microfilaria	Seals	Presence	Ridgeway *et al* 1972
Protozoa			
Giardia	Ringed seals (Arctic)	Antibodies	Olson 1997
Bacteria and fungi			
Vancomycin resistant Enterococci	Black headed gulls (Sweden)	Isolated	Sellin *et al* 2000
Brucella (Brucellosis)	Many marine mammals including seals, whales dolphins	Antibodies, agent isolated	Tryland *et al* 1999, Jensen *et al* 1999, Garner *et al* 1997
Salmonella Antibiotic resistant Salmonella	Californian sea lions. Northern fur seals Black headed gulls (Sweden)	Isolated	Gilmartin 1979, Baker *et al* 1995, Stroud and Roelke 1980 Palmgren *et al* 1997
Leptospirosis (meningoenchephalomyelitis)	California sea lions, northern fur seals	Isolated and antibodies	Dierauf *et al* 1985, Smith 1977
Mycobacterium tuberculosis (tuberculosis)	New Zealand and Australian fur seals, Australian sea lions Arctic marine mammals	Isolated	Forshaw 1991, Cousins *et al* 1993, Romano *et al* 1995 Tryland, 2000
Mycoplasma	Northern hemisphere seals	Isolated and inoculation	Geraci *et al* 1984
Borrelia burgdorferi s.l.	Puffins (Northern Hemisphere)	Isolated	Gylfe *et al* 1999

Aspergillus	Little penguin (Australia)		Obendorf and McColl 1980
Viruses			
Avian paramyxovirus (Newcastle Disease)	Double crested cormorants Little penguins	Clinical signs, agent isolated, antibodies. Antibodies	Meteyer *et al* 1997, Glaser *et al* 1999 Morgan *et al* 1985
Avian influenza (influenza A)	Harbour seals (New England) Ring billed gulls, common terns	Pathology, isolation and inoculation. Antibodies, isolated agent and electron microscopy	Geraci *et al* 1982; Geraci *et al* 1984; Callan *et al* 1995 Graves 1992, Becker 1966
Influenza B	Harbor seals (Dutch coast)	Antibodies and virus isolated	Osterhaus *et al* 2000
Birnavirus (infectious bursal disease virus or Gumboro disease)	Fleshy footed shear water, sooty tern, silver gull	Antibodies	Wilcox *et al* 1983
Calicivirus (San Miguel sea lion virus) (Vesicular disease)	Grey Seals (North Atlantic) White tern	Isolated and electron microscopy Clinical signs, DNA probe	Stack *et al* 1993, Barlough *et al* 1986 Poet *et al* 1996
Parapox virus	Grey Seals (North Atlantic) Manx shearwater	Isolated and electron microscopy. Clinical signs, agent isolated, electron microscopy, inoculation	Stack *et al* 1993; Simpson *et al* 1994; Nettleton *et al* 1995 Nuttal *et al* 1985
Rabies virus	Ringed seals (Svalbard)	Isolated and inoculation	Odegaard 1981
Adenovirus (viral hepatitis)	California seal lions	Isolated and electron microscopy	Brit *et al* 1979; Dierauf 1981
Herpervirus	Harbor seals	Serology, isolated and electron microscopy	Osterhaus *et al* 1985
Unknown virus (puffinosis)	Manx shearwaters	Clinical signs	Harris 1965
Morbilliviruses phocine distemper virus and canine distemper virus	Lake Baikal seals Harbour and grey seals (North and Baltic Seas) Harp seals (Arctic) Monk seals (west Africa) Caspian seals	Mass mortality Isolated Antibodies Antibodies, agent isolated Serology, PCR	Grachev *et al* 1989, Mamaev 1995, Barrett *et al* 1995 Osterhaus *et al* 1988 Goodhart 1988, Dietz *et al* 1989, Markussen and Have 1992, Barrett *et al* 1995 Osterhaus *et al* 1997 Kennedy *et al* 2000

There have been suggestions that some of these diseases are linked to human activity, such as exposure of wildlife to domestic animals (Barrett *et al* 1995), pollution (Harve et al 1999), however, these links are very difficult to prove and there is little conclusive evidence for human involvement. One notable exception is a controlled experiment that indicated pollution might have contributed to the severity and extent of recent morbillivirus infections among seals (Osterhaus *et al* 1995).

Of 22 marine mammal mortality events reported by the US National Marine Mammal Fisheries Service (of NOAA) for the period 1978-1996 (Wilkinson, 1996) bacterial or viral diseases were implicated in 9, algal biotoxins were implicated in 5, environmental extremes (El Nino) were implicated in 2, oil spill or toxic discharge were implicated in 2, gun shot was the cause of 1 and the causes of 4 were not determined (disease and biotoxins were together implicated as the cause of one event). Bacterial or viral diseases have therefore been implicated in nearly half these mass mortality events. Two cases were identified as influenza A virus in seals, two as phocine distemper virus (a morbillivirus), 4 cases as an undetermined morbillivirus (3 in dolphins and 1 in seals) and one case as the bacterial disease, leptospirosis, in sea lions.

The Office International des Epizooties (OIE), the world organisation for animal health, has a list of 15 transmissible diseases (OIE List A) which have the potential for very serious and rapid spread, irrespective of national borders, which are of serious socio-economic or public health consequence and which are of major importance in the international trade of animals and animal products (Table 4). Reports on these diseases must be provided to the OIE when the disease first occurs and at monthly intervals until the area is declared free of the disease. The OIE also has a list of over 90 transmissible diseases (OIE List B) which are considered to be of socio-economic and/or public health importance within countries and which are significant in the international trade of animals and animal products.

Table 4. The OIE List A of transmissible diseases with potential for very serious and rapid spread irrespective of national borders, which are of serious socio-economic or public health consequence and which are of major importance in the international trade of animals and animal products.

Disease and causative agent	**Hosts**	**Mode of transmission**	**Number of ATCP countries experiencing outbreaks (and number of outbreaks in ATCP countries) during 1996-99**
Foot and mouth disease Family: Picornaviradae Genus: Aphthovirus	Most livestock	Direct and indirect contact (droplets). Animate vectors (humans). Inanimate vectors (vehicles etc), airborne (60 km overland, 300 km over sea)	6 (6691)
Vesicular stomatitis	Human	Contamination by	4 (866)

Family: Rhabdoviridae Genus: Vesiculovirus	Domestic: horses, sheep and pigs Wild: white tailed deer and many small tropical mammals	transcutaneous or transmucosal route Arthropod transmission	
Swine vesicular disease Family: Picornaviradae Genus: Enterovirus	Humans Pigs	Direct contact or contact with excretions from infected animals. Faecal contamination Meat scraps and swill	1 (62)
Rinderpest Family: Paramyxoviridae Genus: Morbillivirus	Cattle, sheep, goats and pigs. Many species of wild animal	Direct or close indirect contact	1 (1)
Peste des petits ruminants Family: Paramyxoviridae Genus: Morbillivirus	Sheep and goats. Captive wild ungulates	Direct contact between animals	1 (248)
Contagious bovine pleuropneumonia Bacterial, Mycoplasma Mycoplasma mycoides	Cattle, zebu and water buffalo. Wild bovids are resistant	Aerial, mostly by direct contact: droplets from coughing, saliva and urine	0 (0)
Lumpy skin disease Family: Poxviridae Genus: Capripoxvirus	Cattle, zebu, domestic buffalo, oryx, giraffe and impala	Infected saliva. No specific vector identified but flies and mosquitos could play a role	1 (909)
Rift Valley fever Family: Bunyaviridae Genus: Phlebovirus	Cattle, sheep, goats, camels, rodents, wild ruminants. African monkees and domestic carnivores Human very susceptible	Haematophagous mosquitoes of many genera. Direct contact when handling infected animals and meat	1 (1)
Bluetongue Family: Reoviridae Genus: Orbivirus	Sheep (as disease) also in cattle, goats, camels and wild ruminants as inapparent infection	Biological vectors Culicoides spp.	9 (1973)
Sheep pox and goat pox Family: Poxviridae Genus: Capripoxvirus	Sheep and goats	Direct contact, inhalation, subcutaneous inoculation; indirect transmission by contaminated implements, vehicles or products; insects as mechanical vectors	3 (2148)
African horse sickness Family: Reoviridae Genus: Orbivirus	Reservoir host unknown; usual host are horses, mules, donkeys, zebra; occasionally elephants, onager, camels, dogs	Not directly contagious; usually transmitted by Culicoides spp, occasionally by mosquitoes and ticks	1 (259)
African swine fever Unclassified DNA virus, with	Pigs including some wild pigs	Direct contact with sick animals; feeding on infected meat; soft ticks of	2 (140)

characteristics of Iridovirus and Poxvirus		the genus *Ornithodoros*; vehicles, implements, clothes	
Classical swine fever Family: Flaviviridae Genus: Pestivirus	Pigs and wild boar	Direct contact with sick animals; vistors to infected areas and implements, vehicles; insufficiently cooked waste food fed to pigs	12 (1506)
Highly pathogenic avian influenza Family: Orthomyxoviridae Genus: Influenzavirus A (subtypes H5 and H7)	Isolated in chickens and turkeys; assumed all avians are susceptible	Direct contact with secretions especially faeces; contaminated feed, water, equipment, clothing; carrier waterfowl and sea birds; eggs	2 (77)
Newcastle disease Family: Paramyxoviridae Genus: Paramyxovirus	Many species of domestic and wild birds	Direct contact with secretions especially faeces; contaminated water, clothing, implements; carriers in psittacine and other birds	19 (2623)

Fourteen of the 15 OIE List A diseases have occurred within the 27 Antarctic Treaty Consultative Party (ATCP) countries during the period 1996-1999 for which OIE notification data is currently available. The only List A disease not to have occurred in an ATCP country during the reporting period is contagious bovine pleuropneumonia. 22 of the 27 Antarctic Treaty Consultative Parties reported at least one of the List A diseases within this period. The OIE database records that there have been cases of at least one List A disease in the other five ATCP countries during the 50 years preceding the OIE notification period. Within the ATCP countries the most widely reported List A disease is Newcastle disease, which was reported by 19 ATCP countries in the period 1996-1999. 2623 outbreaks of Newcastle disease were reported from ATCP countries in the period.

The occurrence of OIE List A diseases in ATCP countries indicates that infectious diseases of animals, with the potential for very serious and rapid spread, are occurring in domestic animal stocks and in wildlife populations in countries actively involved in Antarctic operations. Many of the List A diseases require the presence of specific vectors for transmission or for completion of their life cycle. Many of these vectors are not present in Antarctica and therefore these diseases are not likely to infect Antarctic animals. It is also likely that Antarctic wildlife would not be susceptible to many of the List A diseases even if they were to come in contact with them. For example, diseases that are known to be limited to particular animal groups, such as swine vesicular disease, may be less likely to make the switch to Antarctic species than diseases that are known to be capable of infecting diverse species. However, there is good evidence to indicate that Antarctic birds and seals could be susceptible to at least two of the List A diseases. Captive penguins have been diagnosed with the clinical signs of Newcastle disease (Pierson and Pfow 1975) and some non-Antarctic seals have been diagnosed with avian influenza (Geraci et al 1982).

Many important wildlife diseases do not appear on the OIE lists because they are not significant in the international trade of animals and animal products. Occurrences of these diseases are not required to be reported and as a consequence their frequency of occurrence and worldwide regional distribution are not known. It will never be possible to identify in advance all diseases that could be introduced to Antarctic wildlife. Precautions implemented in response to known diseases may also reduce the risk from unknown diseases.

2.5 Characteristics of disease that influence their risk

The individual characteristics of diseases will influence whether they are more likely to be translocated and successfully introduced to previously naïve populations (Table 5). Among the most critical characteristics are the duration of survival of the pathogen in a potentially infective form and its means of transmission (Wilson 1995). Infectious Newcastle disease has been recovered from meat after 250 days at -14°C to -20 °C and from skin and bone marrow after 250 days at -4 °C (Asplin, 1949). Avian Influenza virus can survive in faeces for at least 35 days at 4 °C, virus is stable over a pH range of 5.5 – 8 and can remain infective in lake water for up to 4 days at 22 °C and over 30 days at 0 °C (Webster *et al*, 1978). Survival is prolonged by low relative humidity and low temperature in aerosols whereas low temperature and high moisture levels prolong survival in faeces. Avian Influenza virus survives only several days in carcases at ambient temperature compared with up to 23 days at refrigeration temperatures.

Disease agents that cannot remain viable without a host will not be successfully transferred to Antarctica by people on equipment such as vehicles and clothing. Diseases that require the direct transfer of body fluids are unlikely to be mediated by humans except under very particular circumstances, such as by some invasive scientific procedures. Diseases with an obligate relationship with a specific vector will not become established if the vector is not present.

Table 5. Characteristics of diseases or their causative agents and implications for transmission in Antarctica

Characteristic of disease	Implications for transmission of disease in Antarctica	Examples
Present in animal populations of countries participating in Antarctic activities	Creates the possibility that people or equipment may be in contact with the disease before visiting Antarctica	Newcastle disease, avian influenza
Requires intervention by vector	Disease cannot be transmitted if vector is not present; disease may become a risk if the vector extends its geographic range.	Blue tongue (OIE List A) is unlikely to be a risk to Antarctic wildlife because the vectors, Culicoides spp, are not present. Lyme disease spirochetes may be involved in enzootic cycles on sub-Antarctic islands involving seabirds and the sea-bird associated tick *Ixodes uriae*.
Able to survive well without host	Increases the chance of transmission on equipment, vehicles or clothing	Newcastle disease, avian influenza, infectious bursal disease virus
Tendency to form new strains	Host switching	Morbilliviruses
Ability to infect different hosts across taxonomic groups	Caliciviruses can infect mammals, birds, fish and maybe molluscs	Caliciviruses (Smith *et al* 1998)

Some pathogens, particularly viruses, are capable of infecting different host species. This may be because the pathogen is flexible, such as the caliciviruses, or it may be that it mutates rapidly to form new strains, for example, the morbilliviruses.

Many common diseases, including some of the OIE List A diseases, require a vector for transmission or for completion of their life cycle. Although many disease vectors are not present in Antarctica some, such as ticks of the genus *Ixodes*, have been recorded among parasites collected from Antarctic and sub-Antarctic seals and birds (Table 6).

Table 6. Parasites recorded from Antarctic penguins and seals

	Host species and location	**Reference**
Ectoparasites		
Ticks – *Ixodes*	Penguins and seals – sub-Antarctic and Antarctic Peninsula	Zumpt, 1952, Murray and Vestjens 1967, Hawkey *et al* 1989, Murray *et al* 1990, Bergström *et al* 1999a, Bergström *et al* 1999b
Fleas	Penguins – sub-Antarctic only	Dunnet 1964, Murray *et al* 1967, Murray *et al* 1990
Biting lice	Penguin – most sub-Antarctic and Antarctic species	Murray 1964, Murray *et al* 1990
Sucking lice	Seals – all species	Murray *et al* 1965, Murray 1967, Harder *et al* 1991
Endoparasitic worms		
Nematodes	Penguins and seals	Mawson 1953,
Cestodes	Penguins and seals	Prudoe 1969,
Trematodes	Seals	

Diseases most likely to be of risk of introduction and spread by people are those that are established in the home countries of people visiting the Antarctic, can survive well without a host, do not require a vector that is not present and are able to infect different hosts. There are several diseases, common elsewhere, that are likely to result in the death of many animals if they are introduced successfully to Antarctic populations, examples include Newcastle disease, avian influenza and the morbilliviruses that cause canine and phocine distemper.

3 FACTORS THAT COULD INFLUENCE THE INTRODUCTION AND SPREAD OF DISEASE AMONG ANTARCTIC WILDLIFE

3.1 Environmental conditions

Environmental conditions will influence the chance of disease introduction and spread both directly and indirectly (Table 7). Factors such as temperature, humidity, wind, available water etc will directly influence the survival times of pathogens in the environment. There is little published work on the survivability of pathogens in Antarctica, however, the information available indicates that micro-organisms may survive in Antarctica at least as well as they do in other environments. Human enteric bacteria introduced to the Antarctic environment with untreated sewage effluent are able to persist for long periods (up to 54 days) in a viable but non-culturable state

(Smith *et al* 1994)**.** The human bacterium *Clostridium perfringens* is known to persist in Antarctic marine sediments and be ingested by marine invertebrates (Edwards et al 1998, Conlon et al 2000). There is some indication that seals in the vicinity of a sewage outfall can be infected by *Clostridium perfringens* (McFeters and Edwards, in press, cited in Conlon et al 2000). Environmental conditions may extend the viability of some disease causing agents and reduce the viability of others.

Table 7. Environmental conditions in Antarctica and implications for disease transmission**.**

Environmental condition	Implication to survival or transmission of disease causing agents	Implication to precautions against transmission of disease causing agents
Temperature	Some infectious agents may be susceptible to low temperatures; others may survive well. Temperature controls availability of water (see below). Low temperatures may render introduced vectors immobile but may not effect indigenous vectors.	Low temperature can make otherwise simple precautions difficult or impossible to implement. Warming of parts of Antarctica may increase the range of some vectors.
Humidity	Low humidity may cause desiccation of some pathogens and reduce survival away from a host. Higher humidity in the maritime environment of the Antarctic Peninsula may add transmission by droplets.	
Availability of water	Shortage of water may cause desiccation of some pathogens and reduce survival away from a host	Lack of available water can make otherwise simple precautions difficult or impossible to implement
Winds	High winds may cause desiccation of some pathogens and reduce survival away from a host; wind may assist transmission of disease as aerosol	High winds can make otherwise simple precautions difficult or impossible to implement
Snow cover	Snow at colonies may protect debris, feathers, faeces from dispersion by wind; on melting it provides a source of water	
Sea-ice	Annual sea-ice is transient; a site that is infected by disease-causing agents will eventually be replaced.	For some species replacement of annual sea-ice may provide an effective natural method for limiting disease transfer between years
Distance from other continents	May limit contact with some species including humans	Provides opportunity for quarantine procedures

Environmental conditions across the continent are not constant and regional differences may influence the likelihood of disease transmission. The maritime environment of the Antarctic Peninsula is warmer and more humid than eastern Antarctica. The distance separating Antarctica from other land masses also varies considerably depending on locality and will influence the frequency of interactions between Antarctic species and animals from other regions.

Indirectly the environment determines all aspects of animal behaviour and, as a consequence, can influence disease transfer between animals. The environment also affects the activities that people undertake, which in turn, can influence their role in disease transfer. In particular, the difficult nature of working in Antarctica can reduce human motivation to follow precautionary procedures and, in a practical sense, the scarcity of liquid water at some locations can make otherwise simple precautions a major burden.

3.2 Animal behaviour

Animal behaviour will influence the potential for introduction and spread of infectious disease-causing agents in several ways (Table 8). The tendency to form aggregations will increase the opportunities for infectious agents to be spread within a population. The mode of feeding will influence the probability of coming into contact with the body fluids of other species. Of all feeding types, scavengers and carrion feeders are probably the ones most likely to be in contact with tissues of infected animals or human food. Migration patterns will affect the chance that a species may translocate a disease-causing agent. Many species travel between Antarctica and other regions and may be exposed to diseases by contact with wildlife or as a consequence of human activity, such as waste disposal, in these regions.

The animals most likely to come into contact with pathogens as a result of human activity are those that will feed on waste generated by people given the opportunity. Species that also scavenge at aggregations, such as breeding colonies, are most likely to be agents of disease transfer to other Antarctic species.

Table 8. Behaviour of Antarctic wildlife and implications for disease transmission

Behaviour	Implications to disease transmission	Species
Solitary or colonial		
Solitary or small groups		Leopard seals
Dispersed colony	May have only limited intra-specific interactions within the colony but may form aggregations during the breeding season at other locations	Wilson's storm petrels, snow petrels
Dense colony on ice	Forms colony on 'fresh' ice at the start of each breeding season so no chance that infectious agents remaining from previous season will be transmitted to reformed colony	Emperor penguins
Dense colony on rock	Faeces, feathers etc from previous seasons will be exposed during the summer melt; opportunity for infectious agents to be transmitted from one breeding season to the next	Adélie, chinstrap, gentoo penguins, blue-eyed shag.
Feeding type		
Carnivore – feeding on invertebrates or fish	In general, disease transfer between phyla is less likely than between more closely related species. However, some invertebrate species may act as an intermediate host.	Penguin species, Weddell and crabeater seals
Carnivore – feeding on birds or mammals	May come in contact with diseases that use prey species as reservoir. In general, the more closely related the prey, the more likely it is that diseases carried will be transmissible to the predator. Identical isolates of campylobacter jejuni in prey and predator species within a food chain indicates that pathogens can be passed along the food chain (Olsen pers.	Leopard seals

	comm.)	
Carnivore – scavenger or carrion feeder	Generalist scavengers are most likely to come into contact with disease causing agents, e.g. by feeding on dead and dying diseased animals, by feeding at sewage outlets. Wide ranging scavengers are a likely vector for translocation of disease causing agents. Scavengers and carrion feeders are likely to have evolved effective defence mechanisms against disease	Brown and southern polar skua, northern and southern giant petrel, kelp gull, sheathbill
Aggression		
Non-aggressive	May be the subject of aggression; wounding can create a route for disease transfer	
Displays inter-specific aggression	Aggression leading to wounding can create a route for disease transfer	
Displays intra-specific aggression	Greater opportunity of transfer of diseases requiring direct contact with bodily secretions (mucus, blood, urine, faeces)	
Migration patterns		
Does not migrate	May be local reservoirs of microrganisms	Sheathbills in sub-Antarctica
Travels widely within the Antarctic region	May provide a mechanism for translocation of disease within Antarctica	
Travels between Antarctica and other regions	May be in contact with disease carrying animals from other regions; may feed at rubbish disposal sites, sewage outfalls, abattoir effluent outfalls and other sites where the chances of coming in contact with infectious disease causing agents is high.	Wilson's storm petrel, Southern giant petrel, brown skua, Arctic tern, Antarctic tern, Dominican gull, greater sheathbill, kelp gull, southern elephant seal, fur seals, fin whales, humpback whales, blue whales, minke whales, and possibly many species of dolphin.

4 HUMAN ACTIVITIES WHICH MAY INTRODUCE OR SPREAD DISEASE

4.1 Human activities and their implications for disease introduction or spread

Common human activities undertaken in Antarctica and elsewhere that may lead to disease introduction and spread are listed in Table 9. The type of activities undertaken before going to Antarctica, their locations and subsequent precautions will determine whether people bring infectious disease causing agents with them to Antarctica. The types of activities and how they are undertaken within Antarctica will determine whether pathogens brought into the region could be transmitted to wildlife or whether people could translocate indigenous pathogens.

Table 9. Common human activities and implications for disease transmission in Antarctica

Human activity	Implications for disease transmission
Activities outside Antarctica	
International travel	Travel between countries is recognised as one of the major factors causing the rapid spread of disease around the globe; visits to different countries and different environments increase the chance of coming into contact with a variety of diseases
Visits to farms, abattoirs, food-processing plants, zoos, scientific animal houses etc	Visits to locations where animals are held will all increase the chance of people coming in contact with diseased animals or their products (eg faeces)
Use of equipment in other regions (field training, scientific etc)	Use of Antarctic equipment in other regions will increase the chance that it may be contaminated with disease causing agents
Release of captive animals	The risk of disease introduction associated with re-release to the wild of captive animals has been recognised. SCAR recommends against the release of captive animals, however, there is no specific ATS recommendation on this.
Activities within Antarctica	
Logistics	
Import of equipment, vehicles and clothing	There is no specific AT requirement to clean vehicles, clothing or equipment before sending to Antarctica or moving between locations in Antarctica. However, import of non-sterile soil must be avoided to the maximum extent practicable.
Import of non-indigenous plants and animals	Non-indigenous plants and animals (except food) cannot be introduced to Antarctica without a permit and after use must be disposed of by incineration or equally effective means. These requirements are in response to concerns about the potential for disease introduction with plants or animals, however this remains a risk as there has not been complete compliance
Import of food	No live animals can be imported for food. Precautions are required to prevent the introduction of micro-organisms (eg viruses, bacteria, parasites, yeasts, fungi) not present in the native fauna and flora. Poultry must be inspected for evidence of disease, such as Newcastle's Disease, tuberculosis, and yeast infection. These requirements are in response to concerns about the risk to wildlife of disease associated with food (poultry in particular).
Waste disposal	Human waste and food waste are the most likely sources of bacterial and viral introductions to Antarctica. Whether they contain infectious disease causing agents will depend on their source, treatment and subsequent method of disposal
Sewage treatment	Sewage and domestic waste may be discharged directly to the sea. Treatment, at least by maceration, is required for populations of 30 or more. People will carry many opportunist infectious agents and these will be shed in faeces. Sewage treatment techniques used in Antarctica by most operators are not designed to kill pathogens.
Kitchen waste	Kitchen waste must be either incinerated or removed from the Antarctic. Stored waste needs to be in robust containers to prevent interference by scavengers. Frozen meat including poultry is commonly defrosted in kitchen sinks and the melted water passed through sewage treatment (if present) before disposal to the environment.
Feeding wildlife	Feeding of wildlife is not permitted under many national regulations however feeding of wild life is not specifically prohibited under any AT measure. Feeding of waste food

	(particularly poultry products) to wildlife is among the most direct ways that disease could be introduced to wildlife.
Field camps	The practicalities of living in field camps make some precautions that would be relatively simple to instigate at stations very difficult to follow.
Storage of food	Scavengers may gain access to food or food waste unless precautions are taken.
Waste disposal	Sewage and domestic liquid wastes from field camps cannot be disposed of to ice-free areas or fresh water systems. Waste may be disposed of in deep ice pits. To the maximum extent practicable waste should be removed to stations or ships for disposal. Handling of human waste from field camps can create hygiene and disease risk to people.
Science	Permits from national authorities are required for any direct contact with wildlife. Permits are more likely to be given for scientific purposes than for other types of activities.
Scientific observations	Scientific observations, such as surveys, may not require contact with the animals but may involve approaches closer than otherwise permitted. Surveys at more than one location may create the risk of translocation of microorganisms between sites.
Scientific manipulations	Science involving manipulations of wildlife are the only planned activities in which contact between animals and people occur. Translocation of microorganisms between animals and sites will occur unless hygiene precautions such as cleansing of people and equipment are followed.
Feeding of wildlife for dietary experiments such as the use of radio-labelled food or replacement of food after stomach flushing	Food provided to wildlife could contain disease causing agents.
Recreation	Most visitors to Antarctica, whether as scientists, in support of science or as tourists, will visit breeding aggregations of wildlife, such as penguin colonies, if given the opportunity.
Visits to wildlife aggregations	Recreational visitors to wildlife aggregations will not be in direct contact with animals if normal guidelines are followed. Footwear is likely to be in contact with animal faeces and this could be transferred among locations if precautions such as cleansing are not followed. Several tourism companies use the opportunity to visit multiple wildlife colonies in their marketing. Commercial tourists are usually supervised and return to ship between visits to wildlife colonies. Personnel from national Antarctic programs are more likely to visit wildlife aggregations unsupervised and may visit several colonies, at different locations, in a single day.
Fishing	
Bait used for long-line fishing	Fish used as bait for long-line fishing could be infected with disease causing agents
Waste discharges from fishing boats	Waste discharged from fishing boats is the most significant attractor of wildlife in sub-Antarctic waters

A recent assessment of the risk of disease to wildlife on the Antarctic Peninsula (Pfennigwerth, 2001) developed a qualitative approach to assessing the likelihood that activities would cause a disease event. This method has been adapted and applied here to the activities identified in Table 9. The activities are considered in relation to each of the steps leading to a disease event (Table 10). Likelihood has been assessed on a simple relative scale of low, medium/low, medium, high and very high based on the responses to each of the questions.

Table 10. Qualitative assessment of those activities which may introduce or spread disease causing agents in Antarctica (based on Pfennigwerth, 2001)

Activity	Are pathogens that could cause wildlife disease likely to be present?[1]	If present could pathogens be released during this activity?	If released could pathogens survive in the environment?	Could activity assist pathogens to multiply?	Could activity contribute to dispersal of pathogens?	Could wildlife come into contact with pathogens as a result of this activity?	Relative likelihood of causing disease
Import of equipment, vehicles and clothing	possibly	yes	possibly	no	yes	possibly	low
Import of non-indigenous plants and animals	yes	yes	yes	yes	yes	possibly	high
Import of food	possibly	yes	yes	possibly	yes	possibly	medium
Waste disposal	possibly	yes	possibly	no	possibly	possibly	low
Sewage effluent disposal	possibly	yes	possibly	possibly	yes	yes	medium
Kitchen waste disposal	possibly	yes	yes	possibly	yes	possibly	medium
Deliberate feeding of wildlife	possibly	yes	not necessary, direct transfer possible	yes	yes	yes	very high
Storage of food at field camps	possibly	yes	possibly	possibly	possibly	possibly	medium-low
Waste disposal at field camps	possibly	yes	possibly	possibly	possibly	possibly	medium-low
Scientific observations of wildlife	possibly	yes	possibly	unlikely	yes	possibly	low
Scientific manipulations of wildlife	possibly	yes	not necessary, direct transfer possible	yes	yes	yes	very high
Feeding of wildlife for dietary experiments	possibly	yes	not necessary, direct transfer possible	yes	yes	yes	very high
Discovery of unusual mortality events	possibly	yes	yes	yes	yes	yes	very high
Recreational visits to wildlife aggregations	possibly	yes	possibly	unlikely	yes	possibly	low
Long-line fishing using bait	possibly	yes	not necessary, direct transfer possible	possibly	yes	yes	high

[1]Based on the disease status of operator nations

4.2 Combinations of activities and the risk of disease introduction or spread

This approach is useful for indicating the relative likelihood of disease events arising from individual activities, however, activities do not happen in isolation. Antarctic operations consist of many combinations of these activities. Some will operate synergistically to increase the likelihood, while others will be antagonistic and so reduce the chance of disease introduction. Activities will be combined in many complex ways and may have unpredictable effects on the probability of disease introduction.

Consideration of specific scenarios could assist in focussing attention on activities and combinations of activities that have a greater likelihood of bringing disease into Antarctica.

Scenario 1 – Scientists working on disease in Antarctic wildlife

Among visitors to Antarctica, scientists involved in disease research are more likely than others to be in contact with diseased animals before travelling to Antarctica. Their equipment may be in close contact with animals both in Antarctica and elsewhere, creating opportunities for transfer of pathogens. Their research may entail visiting several sites including breeding aggregations, which creates the possibility of spreading disease-causing agents. All these factors will combine to increase the chance of disease introduction or spread. On the other side of the equation, scientists working in this field are likely to be aware of the risks, should know what precautions are necessary and should have their own procedures for ensuring their studies are not confounded by cross-contamination of samples. Scientists working with wildlife for reasons other than the study of disease will also be in contact with animals if their research involves direct manipulations.

Scenario 2 – Investigation of an unusual mortality event

Unusual mortality events are by their nature unpredictable. It is unlikely that a wildlife mortality event will be discovered by someone with previous experience of such occurrences and it would be unwise to leave decisions on how to react to those discovering a mortality event. Most people do not know normal mortality rates among Antarctic species and may not recognise unusual mortality. A likely first reaction to discovery of an unusual mortality event would be to quickly check other localities to determine the spatial extent of the event. Moving from location to location without some precautions could cause translocation of infection disease causing agents.

Scenario 3 – Use of poultry products by Antarctic personnel

The Madrid Protocol requires that dressed poultry should be inspected for disease before sending to Antarctica because of the perceived risk from diseases such as Newcastle disease, however, inspection is not a reliable method for detecting many diseases including Newcastle disease. Frozen chicken products are commonly thawed in kitchens and the resulting melted liquid discarded with other domestic grey water. Treatment of grey water is limited to the level of treatment available for sewage, which in most cases is not sufficient to kill pathogens. Disposal of sewage effluent is permitted to the marine environment.

Scenario 4 – Recreational visits to wildlife aggregations

Members of national Antarctic programs will frequently take the opportunity to visit breeding aggregations of wildlife for recreational purposes. Those who enjoy outdoor activities are more likely to take the opportunity to visit several breeding sites while in Antarctica. As a generalisation, the type of person who enjoys outdoor pursuits may own their own footwear and use these in preference to footwear issued specifically for Antarctica. They may use their footwear before going to Antarctica, possibly in circumstances that could expose them to pathogens. Currently people visiting Antarctica do not necessarily receive advice to suggest that cleaning of footwear is a sensible precaution.

4.3 Human activities identified as priority risks

The following human activities are identified as the priority risks. Details of the precautions suggested to reduce these risks are to be developed as the second of the three Terms of Reference of the Intersessional Contact Group on Disease in Antarctic wildlife (Practical measures to diminish the risk to Antarctic wildlife of the introduction and spread by human activity of infectious disease causing agents),

1. Feeding of wildlife
2. Actions following discovery of unusual mortality events
3. Research that involves handling of Antarctic animals, particularly research on disease
4. Import of food, particularly poultry products
5. Waste disposal and sewage treatment
6. Use of equipment and clothing before departure to Antarctica
7. Serial visits to wildlife aggregations

5 SUMMARY AND CONCLUSIONS

The following conclusions are numbered sequentially but are grouped according to the section in the report from which they are derived.

Risk Assessment Methodology

1. There is insufficient information available to conduct a reliable quantitative risk assessment of disease introduction and spread to Antarctic wildlife.
2. A qualitative risk assessment approach should be sufficient to indicate priorities for precautionary measures.

Historic Information on Disease

3. No diseases have been demonstrated to have been introduced to Antarctic wildlife or spread by human activities.
4. No systematic studies of disease in Antarctica have been undertaken and it is unlikely that conclusive evidence of human involvement in disease events would be available.
5. There is recent evidence to indicate that some microorganisms have been introduced to Antarctic wildlife and spread as a consequence of human activity.

6. Seven unusual mortality events in which disease was suspected have been recorded for Antarctic wildlife. Only one was investigated and the causes of the others are not known.
7. A seal mass mortality event on the Auckland Islands in 1998 was well investigated but the causal agent is still not known with certainty, indicating that identification of the cause of a mortality event is not always possible.
8. Clinical and serological evidence indicates that many Antarctic and sub-Antarctic penguins and seals have been exposed to infectious disease causing agents, indicating that they are not completely naïve populations with respect to disease.
9. Captive Antarctic birds and seals have exhibited symptoms of a variety of diseases known in other wildlife populations, indicating that they are susceptible to a range of diseases.
10. Disease is suspected in a significant number of the marine mammal mass mortality events reported in non-Antarctic regions.
11. Most of the OIE List A of transmissible diseases with the potential for very serious and rapid spread occur in countries that participate in Antarctic activities. This indicates that, despite the economic incentives to prevent them and the large preventive effort, serious transmissible disease of animals occur in most countries.
12. Most OIE List A diseases would not be transmissible to birds and seals, however, there is evidence that birds and seals are susceptible to some, such as Newcastle disease and avian influenza.
13. Newcastle disease has occurred widely in ATCP countries in recent years and may be the disease most likely to be a risk to Antarctic wildlife.
14. Diseases most likely to be of risk of introduction and spread by people are those that are established in the home countries of people visiting Antarctica, can survive well without a host, do not require a vector that is not present and can infect different hosts, examples include Newcastle disease, avian influenza and the morbilliviruses causing canine and phocine distemper.
15. It is not possible to identify all diseases with the potential for introduction and this is not necessary as a precursor to implementation of precautions.

Factors that could influence disease introduction or spread

16. Environmental conditions in parts of the Antarctic are similar to conditions elsewhere and so mechanisms for disease transfer that occur in these places are likely to also occur in Antarctica.
17. The cold and lack of available water may make otherwise simple precautions difficult or impossible under some circumstances such as at remote field locations.
18. Animal behaviour will influence the likelihood of disease transmission within populations and between species.
19. Several Antarctic species migrate beyond the Antarctic to regions where they could be in contact with disease causing agents carried by other wildlife and in human waste at sewage effluent outfalls and waste disposal tips.
20. Carrion feeders are most likely to be in direct contact with diseased or dying animals of other species.
21. Opportunist scavengers are most likely to feed on waste generated by human activity if precautions are not taken to prevent access.

22. Skuas are among the most likely species to be the point of entry of disease from waste because they are not shy of people and they will scavenge on station waste given the opportunity. They are also among the most likely routes of transfer to other species because of their habit of associating with other species.

Human activities which may introduce or spread disease

23. Activities undertaken before going to Antarctica, including precautions, will determine whether people bring infectious disease with them.
24. Activities in Antarctica most likely to cause disease introduction or spread are those that involve close contact with wildlife or those that allow wildlife to come in contact with waste generated from human activities.
25. Certain combinations of activities may significantly increase the risks.
26. Precautions should be prioritised to target the most likely pathways of disease introduction or spread.
27. Human activities identified as priorities for practical measures to diminish risk are,
    - Feeding of wildlife
    - Actions following discovery of unusual mortality events
    - Research that involves handling of Antarctic animals, particularly research on disease
    - Import of food, particularly poultry products
    - Waste disposal and sewage treatment
    - Use of equipment and clothing before departure to Antarctica
    - Serial visits to wildlife aggregations

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ATTACHMENT 1 – RISK ASSESSMENT PROCESS

Processes called *risk analysis* are used in many different fields and different terminologies have evolved. In veterinary medicine the phrase *risk analysis* is generally used as the term for the overall process for dealing with risks. In the framework established by the Office International des Epizooties (OIE), the world organisation for animal health, risk analysis consists of,

- Hazard identification – the process of identifying pathogenic agents that could be introduced
- Risk assessment – evaluation of the likelihood and consequences of introducing a pathogen
- Risk management – the process of identifying, selecting and implementing measures to reduce the level of risk, including determination of acceptable risk
- Risk communication – the interactive exchange of information on risk among interested parties

The process of hazard identification used here was to review historic information on wildlife diseases in Antarctica and from elsewhere to determine if particular diseases should be a concern. Risk was assessed using information on the nature of the pathogens, environmental conditions, the biology and behaviour of the animals of concern and the activities of people visiting Antarctica. Risk management and risk communication are the subject of the other terms of reference of this intersessional contact group.

Risk is the product of the likelihood of an event happening and the consequences of the event should it occur. The smallest risks are associated with activities that are unlikely to occur and are of little consequence; the greatest risks are those that are likely to occur and are of great consequence. Between these extremes are various combinations of likelihood and consequence (Table 11).

Table 11. Level of risk based on assessment of likelihood of an event and consequences of the event

Likelihood	Severity of consequences				
	extreme	**very high**	**medium**	**low**	**negligible**
almost certain	very severe	severe	high	major	significant
likely	severe	high	major	significant	moderate
moderate	high	major	significant	moderate	low
unlikely	major	significant	moderate	low	very low
extremely unlikely	significant	moderate	low	very low	negligible

Risk assessments may be either quantitative or qualitative; both approaches will involve some degree of uncertainty. Qualitative risk assessments may appear to be more objective however this may be illusionary. If probability data are not available, but are estimated and the estimates are subsequently used as the basis for calculation of likelihood, the subjective nature of the assessment may be obscured. Any risk assessment should include an indication of the source and scale of uncertainty in the information on which it is based.

Risk management is based on the precept that risk cannot be eliminated completely but if the sources of greatest risk are recognised in advance they can be reduced. An important component of risk management is the decision on what constitutes an acceptable risk.

Likelihood

In a quantitative risk assessment, such as those for the importation of farm animals to a country (Hayes, 1997), the risk assessment may commence with review of the prevalence of the infectious agent in the country of origin. The next step would be to assign a probability to each of the steps that must be completed if the disease is to be established in the importing country. For a disease to cause an epidemic a series of steps must each take place. In a quantitative assessment the overall probability for successful disease introduction is calculated as the product of the individual probabilities of each step. For this process to be applied to disease importation to Antarctic wildlife, the probability of each of the following would be required,

1. a piece of equipment, food or a person is infected with the disease causing agent;
2. the agent survives handling, treatment and transit time;
3. wildlife are exposed to the agent;
4. the agent is exposed to a portal of entry (e.g. a wound, inhaled etc);
5. the agent induces infection;
6. the infection induces disease; and,
7. the disease spreads.

When this process is used in non-Antarctic regions probabilities are estimated on the basis of prior information. For Antarctic activities, sufficient information is not currently available to provide a meaningful estimate of probability for any of the steps. Because the method is based on the mathematical product of the probabilities of each step, the individual uncertainties associated with each step compound; as a consequence it is unlikely that a method based on the probabilities for a series of steps will be useful at this stage.

An alternative, qualitative approach used here is to consider the range of possible consequences of disease introduction and to assign a rough indication of the likelihood that each consequence could occur. This is used as the basis for determining whether any of the possible consequences are a sufficiently high risk that precautionary measures are warranted. The next step is to identify qualitatively which human activities are most likely to create exposure and transmission pathways, and which species are most vulnerable. This information may then be used as the basis for practical measures to reduce risk.

After the qualitative risk assessment, if it is still unclear whether the risks are sufficient to warrant preventative measures, it may be necessary to embark on an extensive information gathering process to acquire data sufficient for a quantitative risk assessment. This effort should not be necessary if the qualitative assessment clearly indicates that there are significant risks that could be prevented or that the risks are acceptable.

Consequences

Some potential consequences of taking pathogens to Antarctica, listed in increasing order of severity and reducing likelihood, are,

1. the pathogen is not exposed to a suitable host and dies;
2. transient sickness and distress to individual animals;
3. establishment of a non-native micro-organism;
4. loss of productivity or breeding success;
5. death of a few animals;
6. death of many animals;
7. eradication of local populations;
8. disruption of a component of the ecosystem;
9. extinction of a species.

It is inevitable that people will take some pathogens with them when they visit Antarctica. Pathogens that are taken to Antarctica and subsequently die without infecting a suitable host will have a negligible impact. Their effects, if any, are of little consequence as they are both short-term and local. A pathogen that becomes established within a population without causing the outward signs of disease may have no ecological effect but may become a long-term addition to the biota of Antarctica. A pathogen that becomes established without causing disease may have a minor impact on the population and may have no wider ecological implications, however, if it is established, it is, by definition, not transitory.

Pathogens that cause sickness and distress to infected animals may have transient effects on individual animals and may have few, if any, wider ecological consequences. However, if the disease persists in the population and continues to infect other individuals, the consequences of the introduction are not transient. Diseases that cause the death of animals obviously have a permanent effect on the infected animals. Whether the disease causes lasting change to a population or has wider ecological implications will depend on a number of factors, including the number, age-cohort or sex of animals killed.

Extinction of a species is the most serious effect that any human activity could cause because it is both permanent and widespread. However, experience in other regions indicates that species extinction is a very unlikely consequence of disease introduction without the co-occurrence of other stress factors.

Overall risk

It is impossible to accurately predict the likelihood and consequences of disease introduction to a population in which the disease has not previously occurred (Table 12). Both likelihood and consequences will vary according to characteristics of the pathogen and the affected species, including host range, means of transmission, degree of exposure, immune status and response to the potential hosts. In general, the consequences of disease are more severe in naïve populations than in populations previously exposed. Knowledge of the full consequences of introduction is not a necessary precursor to the implementation of methods to reduce the likelihood of an introduction. If establishment of a non-native pathogen is undesirable and precautions are taken to reduce the likelihood of this happening, these precautions will also reduce the likelihood of other, more serious consequences such as death of animals.

Table 12. Potential consequences of taking pathogens to Antarctica and their likelihood, severity and indication of the overall risk.

Potential consequence	Likelihood	Severity of consequences	Overall risk
1. pathogens are introduced but are not exposed to a suitable hosts and die;	certain	negligible	significant
2. transient sickness and distress to individual animals;	moderate	low	moderate
3. establishment of a non-native micro-organism;	moderate	medium	significant
4. loss of productivity or breeding success;	moderate	medium	significant
5. death of a few animals;	moderate	medium	significant
6. death of many animals;	unlikely	very high	significant
7. eradication of local populations;	unlikely	very high	significant
8. disruption of a component of the ecosystem;	unlikely	extreme	major
9. extinction of a species.	extremely unlikely	Extreme	significant