Polar Biol (2009) 32:1095–1115
DOI 10.1007/s00300-009-0640-3

REVIEW

Health of Antarctic birds: a review of their parasites, pathogens and diseases

Andrés Barbosa · María José Palacios

Received: 13 October 2008 / Revised: 17 April 2009 / Accepted: 21 April 2009 / Published online: 12 May 2009

Abstract Antarctic birds are not beyond the effects of parasites or pathogens. However, potential ecological consequences of wide-spread infections for bird populations in Antarctica have received little attention. In this paper, we review the information published about disease and parasites, and their effects on Antarctic birds. The information on host species, parasites and pathogens, and geographic regions is incomplete and data on ecological effects on the populations, including how birds respond to pathogens and parasites, are almost inexistent. We conclude that more research is needed to establish general patterns of spatial and temporal variation in pathogens and parasites, and to determine how such patterns could influence hosts. This information is crucial to limit the spread of outbreaks and may aid in the decision-making process should they occur.

Keywords Antarctic birds · Bacteria · Disease · Health · Parasite · Virus

Introduction

Disease is one of the main agents of morbidity and mortality in living organisms (Haldane 1949). A single outbreak can decimate animal populations. Some examples include the death of 18,000 seals in Northern Europe from the Phocine Distemper Virus (Jensen et al. 2002), the loss of 40,000 Mallards due to the appearance of new diseases (Friend 2006), a decrease in the population of North American House Finch due to Mycoplasma conjunctivitis (Hochachka and Dhondt 2000) and the decline of several species of frogs in Australia from a virus infection (Laurance et al. 1996), among others. However, disease (including both effects of microbes and parasites) has only recently been recognized as an active player in ecosystems through its effects on host populations (Grenfell and Dobson 1995).

Infectious disease outbreaks can lead to catastrophic population reductions. However, pathogens and parasites can also cause variations in metabolic rate (e.g., Møller et al. 1994), and influence life history traits, such as the phenology of reproduction, clutch size, and brood size (see revision in Møller 1997), the expression of secondary sexual characters (Hillgarth and Wingfield 1997) as well as social status (Rau 1983).

Despite their geographical isolation, habitats such as the Antarctic ecosystems are not beyond the risk posed by pathogens and/or parasites. So far, only a few events of mass mortality have been reported (Kerry et al. 1999) and no major outbreaks of infectious diseases have been described in Antarctica (Weimerskirch 2004), although some were reported from remote islands in the Southern Ocean (Weimerskirch 2004).

However, increased warming across the continent (see Steig et al. 2009) may make the survival of pathogens and large-scale outbreaks more likely.

During the “Workshop on diseases in Antarctic Wildlife” held in Hobart in 1998 a number of recommendations were made for their monitoring and prevention of Antarctic

A. Barbosa (✉) · M. J. Palacios
Departamento de Ecología Funcional y Evolutiva, Estación Experimental de Zonas Áridas, CSIC, C/General Segura, 1, 04001 Almeria, Spain
e-mail: barbosa@mncn.csic.es

Present Address:
A. Barbosa
Departamento de Ecología Evolutiva, Museo Nacional de Ciencias Naturales, CSIC, C/José Gutiérrez Abascal, 2, 28006 Madrid, Spain

Treaty Consultative Meeting (ACTM) (Kerry et al. 1999). One of the recommendations was to establish that "a structured research program is required to provide information about what is normal and what is aberrant in the health of Antarctic species" (Kerry et al. 1999). However, to date this has not yet been achieved. What is required is an in-depth review on the epidemiology of diseases and their status in any Antarctic birds. The only review currently available focuses solely on penguins (see Clarke and Kerry 2000). This information is important in terms of ecosystem health, as any variation in the prevalence of a disease in species may be a sign of "ecosystem distress syndrome" (Rapport 2007). Global change is one of the main factors affecting ecosystem health through the relationship between climate change and global human travel, and the increase of distribution ranges, abundance and/or virulence of parasites and pathogens (Daszak et al. 2000; Sutherst 2001, Harvell et al. 2002; Epstein et al. 2003). In Antarctica, especially the Antarctic Peninsula and West Antarctica, temperatures have risen (Turner et al. 2004; IPCC 2007; Steig et al. 2009). Furthermore, human activities, such as research stations, as well as increasing tourism activities can facilitate the spread of disease (Curry et al. 2002). Research activities tend to concentrate on relatively small areas or specific locations while tourists visit a great number of colonies in a short span of time. It is worth mentioning that tour companies that are members of the International Antarctic Tour Operator (IAATO) have a boot-cleaning policy which may reduce such risk, as long as it is carried out thoroughly. Companies that are not IAATO members and private vessels are more likely to contribute to the spread of disease. Finally, disease can also be spread by migratory species. These species are thought to be responsible for transmission of several viruses, such as influenza or New Castle disease, bacteria, such as *Campylobacter jejuni*, *Pasteurella multocida*, *Clostridium botulinum* and *Mycobacterium avium*, and protozoa, such as *Cryptosporidium* sp (Hubalek 2004). These agents are a recognized risk in Antarctica (Kerry et al. 1999).

The aim of this paper is to compile published information on the presence and the effects of disease, pathogens and parasites in Antarctic birds to provide a baseline for the evaluation of the health of the Antarctic ecosystem.

Materials and methods

The information was taken from papers referenced in the Zoological Record and PubMed database and from in-depth bibliographical research. Antarctic birds were those non-passerines included in the book, "A Complete Guide to Antarctic Wildlife" (Shirihai 2002) breeding and distributed in Antarctica and sub-Antarctic islands south of 45°S (see Frenot et al. 2005 for a similar consideration of Antarctic territory). We examined information for 46 bird species (Table 1). Data on whether microorganisms (virus and bacteria) were detected by means of serology or by isolation were given as well as information about geographical location.

Results and discussion

We reviewed 101 published papers dealing with issues related to parasites, pathogens or diseases (Table 1), and found information on 38 out of 46 (82%) bird species searched. The number of publications per species was highly variable (Table 1). For example, Adelie (*Pygoscelis adeliae*), the Gentoo (*Pygoscelis papua*), and the Chinstrap (*Pygoscelis antarctica*), as well as kelp gulls (*Larus dominicanus*), were mentioned in more than 15 publications compared to only three dealing with Antarctic terns (*Sterna vittata*). With respect to disease agents (or antibodies) reportedly in Antarctic birds, bacteria were detected in 15 species (33%), viruses in 9 (20%), protozoa in 14 (30%), gastrointestinal parasites in 20 (44%), and ectoparasites in 37 species (80%) (Table 1). The species with the highest number of parasites or pathogens described are the three pygoscelid penguins, the giant petrels (*Macronectes giganteus*), sub-Antarctic skuas (*Catharacta skua lonnbergi*), sheathbills (*Chionis alba*), and kelp gulls (*Larus dominicanus*). However, this difference is probably more a reflection of the differences in research effort rather than based on biological reasons.

The distribution of parasites and pathogens in Antarctic birds shows that seven viruses are likely to be present, of which only paramyxovirus and poxvirus have been isolated (Table 1). The viruses responsible for infectious bursal disease, Newcastle disease and influenza have only been reported from serological studies and have never been isolated in Antarctica (Morgan et al. 1981; Morgan and Westbury 1981; Austin and Webster 1993; Gardner et al. 1997; Gauthier-Clerc et al. 2002; Baumeister et al. 2004; Wallensten et al. 2006; Miller et al. 2008). Moreover in the studies where isolation or direct detection (i.e., PCR methods) was carried out, results have been negative (Morgan and Westbury 1988; Wallensten et al. 2006). Thus, if the presence of viruses is implied and solely determined by serological techniques, caution, needs to be applied when interpreting the results and further studies applying direct detection or isolation should be carried out to confirm or reject the presence of a certain organism. Of the 42 bacteria reported in Antarctic birds, 37 were isolated, and seven were detected only by serological techniques. The main bacteria detected were *Campylobacter lari*, the common bacteria causing enteritis in birds and

Table 1 Microorganisms, diseases and parasites present in Antarctic birds

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
Aptenodytes patagonicus	*Borrelia burgdorferi* A 1 (1)	Infectious Bursal Disease A 1 (2)	*Plasmodium relictum* 1 (5)	*Tetrabothrius* sp 1 (6)	*Ixodes uriae* 1 (1)	
		NewCastle Disease A 1 (2)		*Tetrabothrius pauliani* 1 (7)	*Ixodes uriae* 1 (9)	
		Influenza A 1 (2)		*Contracaecum* sp 1 (8)	*Ixodes uriae* 1 (10)	
		Flavivirus A 1 (3)			*Ixodes uriae* 1 (11)	
		Paramyxovirus I 1 (4)			*Austrogoniodes brevipes* 1 (12)	
					Austrogoniodes brevipes 1 (13)	
					Austrogoniodes brevipes 1 (98)	
					Nesiotinus demersus 1 (13)	
					Nesiotinus demersus 1 (98)	
					Nesiotinus demersus 1 (14)	
Aptenodytes forsteri	*Chlamydia* sp I 4 (15)	Infectious Bursal Disease A 4 (16)		*Tetrabothrius* sp 4 (6)	*Austrogoniodes mawsoni* 4 (12)	
				Tetrabothrius wrighti 4 (7)	*Austrogoniodes mawsoni* 4 (13)	
				Parorchites zederi 4 (7)		
Pygoscelis papua	*Chlamydia* sp A 1 (17)	Influenza A 1 (39)	*Plasmodium relictum* 1 (5)	*Stegophorus macronectes* 1 (8)	*Austrogoniodes gressitti* 1 (12)	
	Salmonella enteriditis I 1 (18)	Coronavirus CS 1 (40)	*Eimeria pygosceli* 2 (25)	*Contracaecum heardi* 1 (8)	*Parapsyllus longicornis* 1 (34)	
	Salmonella havana I 1 (19)	Influenza A 2 (24)	*Isospora* sp 2 (25)	*Stomachus* sp 1 (8)	*Naubates prioni* 1 (14)	
	Salmonella typhymurium I 1 (19)		*Cryptosporidium* sp 3 (26)	*Tetrabothrius pauliani* 1 (7)	*Austrogoniodes gressitti* 1 (98)	
	Salmonella enteriditis I 1 (19)		*Sarcocystis* sp 3 (27)	*Parorchites zederi* 2 (28)		
	Rickettsia-like organism I 1 (20)			*Parorchites zederi* 2 (29)		
	Escherichia intermedia I 2 (21)			*Parorchites zederi* 2 (30)		
	Bacillus circulans I 2 (21)			*Streptocara* sp 2 (31)		
	Bacillus sphaericus I 2 (21)			*Contracaecum* sp 2 (31)		
	Bacillus cereus I 2 (21)			*Tetrabothrius* sp 2 (31)		

Table 1 continued

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
	Bacillus megatherium I 2 (21)			*Tetrabothrius* sp 3 (32)		
	Alcaligenes aquamarinus I 2 (21)			*Ascaridia* sp 3 (32)		
	Achromobacter sp I 2 (21)			*Contracaecum* sp 3 (32)		
	Actinomyces sp I 2 (21)			*Corynosoma bullosum* 3 (33)		
	Bacillus subtilis I 2 (22)			*Corynosoma shackletoni* 3 (33)		
	Enterococcus faecalis I 2 (22)					
	Campylobacter lari I 2 (23)					
	***Salmonella* sp I 2 (23)**					
	***Yersinia* sp I 2 (23)**					
	***Campylobacter jejuni* I 2 (23)**					
	Campylobacter lari I 3 (23)					
Pygoscelis adeliae	*Campylobacter lari* I 3 (35)	Influenza A 3 (24)	*Eimeria pygosceli* 2 (25)	*Parorchites zederi* 2 (28)	***Glaciopsyllus antarcticus* 4 (48)**	
	Campylobacter lari I 3 (23)	**Influenza I 3 (39)**	*Isospora* 2 (25)	*Tetrabothrius pauliani* 2 (28)	*Ixodes uriae* 4 (12)	
	Pasteurella multocida I 3 (36)	Infectious Bursal Disease A 4 (16)	*Cryptosporidium* sp 3 (45)	*Parorchites zederi* 4 (7)	*Austrogoniodes antarcticus* 4 (12)	
	Escherechia coli A 3 (37)	Influenza A 4 (41)	*Sarcocystis* sp 3 (27)	*Stegophorus macronectes* 4 (47)	*Austrogoniodes antarcticus* 4 (13)	
	Staphylococcus sp A 3 (37)	Influenza A 4 (43)	*Coccidia* sp 4 (46)			
	Clostridium cadaveris A 3 (37)	Paramyxovirus I 4 (41)				
	Clostridium sporogenes A 3 (37)	Paramyxovirus I 4 (44)				
	***Salmonella* sp I 3 (23)**	Paramyxovirus A 4 (43)				
	***Yersinia* sp I 3 (23)**	Paramyxovirus I 4 (4)				
	***Campylobacter jejuni* I 3 (23)**	NewCastle Disease A 4 (43)				

Table 1 continued

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
	Mycoplasma gallisepticum A 3 (42)	**NewCastle Disease I 4 (44)**				
	Mycoplasma synoviae A 3 (42)	**Influenza I 4 (44)**				
	Salmonella gallinarum A 3 (42)					
	Salmonella pullorum A 3 (42)					
	Chlamydia sp A 4 (17)					
	Salmonella sp I 4 (38)					
Pygoscelis antarctica	*Staphylococcus saprophyticus* I 2 (21)	Influenza A 2 (24)	*Eimeria pygosceli* 2 (25)	*Parorchites zederi* 2 (28)	*Austrogoniodes gressitti* 1 (12)	
	Alcaligenes aquamarinus I 2 (21)	**Influenza I 2 (39)**	*Isospora* sp 2 (25)	*Parorchites zederi* 2 (29)	*Austrogoniodes macquariensis* 1 (98)	
	Micrococcus varians I 2 (21)		*Sarcocystis* sp 3 (27)	*Tetrabothrius pauliani* 2 (28)		
	Micrococcus nishinomiyaensis I 2 (21)		**Blood parasites 2 (49)**	*Tetrabothrius pauliani* 2 (30)		
	Bacillus circulans I 2 (21)			*Tetrabothrius pauliani* 2 (50)		
	Bacillus megatherium I 2 (21)			*Tetrabothrius joubini* 2 (28)		
	Bacillus sphaericus I 2 (21)			*Tetrabothrius joubini* 2 (29)		
	Eubacterium alactolyticum I 2 (21)			*Tetrabothrius joubini* 2 (30)		
	Sarcina ureae I 2 (21)			*Corynosoma pseudohamanni* 2 (72)		
	Streptococcus faecalis I 2 (21)					
	Escherichia coli I 2 (21)					
	Corynebacterium sp I 2 (21)					
	Bacillus coagulans I 2 (22)					

Table 1 continued

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
	Pseudomonas fluorescens I 2 (22)					
	***Salmonella* sp I 2 (23)**					
	***Yersinia* sp I 2 (23)**					
	***Campylobacter lari* I 2 (23)**					
	***Campylobacter jejuni* I 2 (23)**					
Eudyptes chrysocome	*Chlamydia* sp A 1 (17)			*Stegophorus macronectes* 1 (8)	*Austrogoniodes hamiltoni* 1 (12)	
				Contracaecum sp 1 (8)	*Austrogoniodes hamiltoni* 1 (14)	
					Austrogoniodes hamiltoni 1 (98)	
					Austrogoniodes macquariensis 1 (13)	
					Austrogoniodes macquariensis 1 (14)	
					Austrogoniodes macquariensis 1 (98)	
					Austrogoniodes cristati 1 (14)	
					Austrogoniodes cristati 1 (98)	
					Austrogoniodes concii 1 (98)	
Eudyptes chrysolophus	*Campylobacter jejuni* I 1 (51)	Paramyxovirus I 1 (4)		*Stegophorus macronectes* 1 (8)	*Ixodes uriae* 1 (10)	
				Contracaecum heardi 1 (8)	*Ixodes uriae* 1 (52)	
				Tetrabothrius sp 3 (50)	*Ixodes uriae* 1 (53)	
					Austrogoniodes cristati 1 (14)	
					Austrogoniodes cristati 1 (98)	
					Austrogoniodes hamiltoni 1 (14)	
					Austrogoniodes macquariensis 1 (14)	
					Austrogoniodes macquariensis 1 (98)	
					Austrogoniodes bicornutus 1 (98)	

Table 1 continued

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
Eudyptes schlegeli	*Chlamydia* sp A 1 (17)	Flavivirus A 1 (3)		*Stomachus* sp 1 (8)	*Ixodes uriae* 1 (53)	
		NewCastle Disease A 1 (3)		*Terranova piscium* 1 (8)	*Austrogoniodes hamiltoni* 1 (12)	
					Austrogoniodes hamiltoni 1 (13)	
					Austrogoniodes hamiltoni 1 (98)	
					Austrogoniodes cristati 1 (98)	
Diomedea exulans			*Hepatozoon albatrossi* 1 (54)		*Ixodes uriae* 1 (53)	
					Docophoroides brevis 1 (55)	
					Docophoroides brevis 1 (98)	
					Naubates fuliginosus 1 (55)	
					Naubates fuliginosus 1 (98)	
					Pseudonirmus gurlti 1 (55)	
					Trabeculus hexacon 1 (55)	
					Docophoroides brevis 1 (14)	
					Harrisoniella hopkinsi 1 (14)	
					Harrisoniella hopkinsi 1 (98)	
					Paraclisis hyalina 1 (14)	
					Paraclisis hyalina 1 (98)	
					Naubates pterodromi 1 (14)	
					Austromenopon affine 1 (98)	
					Perineus concinnoides 1 (98)	
					Episbates pederiformis 1 (98)	
Thalassarche melanophrys	***Salmonella havana* I 1 (19)**		*Hepotozoon albatrossi* 1 (54)	*Stomachus* sp 1 (8)	*Ixodes uriae* 1 (52)	
	***Salmonella typhimurium* I 1 (19)**				*Ixodes uriae* 1 (56)	
	***Salmonella enteriditis* I 1 (19)**				*Paraclisis diomedeae* 1 (14)	
					Paraclisis diomedeae 1 (98)	
					Perineus circumfasciatus 1 (14)	
					Perineus circumfasciatus 1 (98)	
					Austromenopon affine 1 (98)	
					Harrisoniella ferox 1 (98)	
					Docophoroides simplex 1 (98)	

Table 1 continued

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
Thalassarche chrysostoma	***Salmonella havana* I 1 (19)**		*Hepatozoon albatrossi* 1 (54)		*Ixodes uriae* 1 (52)	
	***Salmonella typhimurium* I 1 (19)**				*Docophoroides simplex* 1 (14)	
	***Salmonella enteriditis* I 1 (19)**				*Paraclisis diomedeae* 1 (14)	
					Paraclisis diomedeae 1 (98)	
					Austromenopon affine 1 (98)	
					Perineus circumfasciatus 1 (98)	
Thalassarche chlororhynchos	*Pasteurella multocida* I 1 (57)					
	Erysipelothrix rhusiopathiae I 1 (57)					
Phoebetria palpebrata				*Seurati shipleyi* 1 (8)	*Ixodes uriae* 1 (53)	
				Paranisakiopsis sp 1 (8)	*Ixodes kerguelensis* 1 (58)	
					Paraclisis diomedeae 1 (14)	
					Paraclisis diomedeae 1 (98)	
					Perineus circumfasciatus 1 (14)	
					Perineus circumfasciatus 1 (98)	
Macronectes giganteus	*Pasteurella multocida* I 2 (59)	Influenza A 2 (24)	*Sarcocystis* sp 3 (27)	*Capillaria convoluta* 1 (8)	*Ixodes uriae* 1 (53)	
	Escherichia coli I 2 (59)	Poxvirus I 3 (99)		*Stegophorus macronectes* 2 (47)	*Parapsyllus cardinis* 1 (53)	
	Enterococcus faecalis I 2 (21)			*Stegophorus arctowski* 2 (47)	***Glaciopsyllus antarcticus* 4 (48)**	
	Bacillus subtilis I 2 (21)				*Docophoroides murphyi* 1 (14)	
	Brevibacterium brunneum I 2 (21)				*Docophoroides murphyi* 1 (98)	
	Escherichia coli I 2 (21)				*Paraclisis obscura* 1 (14)	
	Alcaligenes faecalis I 2 (21)				*Paraclisis obscura* 1 (98)	
	Plesiomonas sp I 2 (21)				*Perineus macronecti* 1 (14)	
	Mycoplasma gallisepticum A 3 (42)				*Austromenopon ossifragae* 1 (98)	
	Mycoplasma synoviae A 3 (42)				*Perineus circumfasciatus* 1 (98)	

Table 1 continued

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
	Salmonella gallinarum A 3 (42)				*Saemundssonia gaini* 1 (98)	
	Salmonella pullorum A 3 (42)					
	***Campylobacter lari* I 2 (23)**					
	***Campylobacter jejuni* I 2 (23)**					
	***Salmonella sp* I 2 (23)**					
	***Yersinia sp* I 2 (23)**					
Macronectes halli					*Docophoroides murphyi* 1 (14)	
					Paraclisis obscura 1 (14)	
					Perineus macronecti 1 (14)	
Fulmarus glacialoides					*Glaciopsyllus antarcticus* 4 (48)	
					Glaciopsyllus antarcticus 4 (60)	
					Glaciopsyllus antarcticus 4 (61)	
					Glaciopsyllus antarcticus 4 (62)	
Thalassoica antarctica				*Tetrabothrius* sp 1 (6)	*Saemundssonia nivea* 1 (98)	
					Glaciopsyllus antarcticus 4 (48)	
					Zachvatkinia stercorarii 4 (63)	
Daption capense			*Sarcocystis* sp 3 (27)	*Tetrabothrius kowalewskii* 2 (101)	*Docophoroides brevis* 1 (55)	
					Naubates fuliginosus 1 (55)	
					Pseudonirmus gurlti 1 (55)	
					Pseudonirmus gurlti 1 (98)	
					Trabeculus hexacon 1 (55)	
					Glaciopsyllus antarcticus 4 (62)	
					Glaciopsyllus antarcticus 4 (48)	

Table 1 continued

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
Pagodroma nivea					*Glaciopsyllus antarcticus* 4 (48)	
					Glaciopsyllus antarcticus 4 (65)	
					Glaciopsyllus antarticus 4 (62)	
					Glaciopsyllus antarticus 4 (60)	
					Saemundssonia antarctica 4 (91)	
					Pseudonirmus charcoti 4 (91)	
Pterodroma lessoni					*Ixodes uriae* 1 (53)	
					Parapsyllus heardi 1 (53)	
					Parapsyllus cardinis 1 (53)	
					Halipeurus procellariae 1 (14)	
					Halipeurus procellariae 1 (98)	
					Naubates pterodromi 1 (14)	
					Naubates heteroproctus 1 (14)	
					Naubates heteroproctus 1 (98)	
					Saemundssonia sp 1 (14)	
					Trabeculus schillingi 1 (14)	
					Trabeculus schillingi 1 (98)	
Pterodroma mollis					*Trabeculus schillingi* 1 (98)	
					Halipeurus procellariae 1 (98)	
					Halipeurus heraldicus 1 (98)	
Holobaena caerulea					*Notiopsylla enciari* 1 (66)	
					Parapsyllus heardi 1 (67)	
					Ancistrona vagelli 1 (14)	
					Naubates clypeatus 1 (14)	
					Naubates clypeatus 1 (98)	
					Saemundssonia pterodromae 1 (14)	
					Saemundssonia pterodromae 1 (98)	
					Ancistrona sp 1 (98)	

Table 1 continued

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
Pachyptilla desolata					*Ixodes uriae* 1 (53)	
					Ixodes pterodromae 1 (53)	
					Parapsyllus heardi 1 (67)	
					Parapsyllus cardinis 1 (53)	
					Notiopsylla kerguelensis 1 (53)	
					Zachvatkinia sp 1 (68)	
					Ancistrona vagelli 1 (14)	
					Ancistrona sp 1 (98)	
					Longimenopon galeatum 1 (14)	
					Longimenopon galeatum 1 (98)	
					Naubates prioni 1 (14)	
					Naubates prioni 1 (98)	
					Naubates clypeatus 1 (14)	
					Halipeurus diversus 1 (14)	
					Halipeurus turtur 1 (98)	
					Trabeculus sp 1 (14)	
Pachyptilla turtur					*Naubates prioni* 1 (98)	
Procellaria aequinoctialis					*Ixodes kerguelensis* 1 (58)	
					Zachvatkinia robusta 1 (68)	
					Docophoroides brevis 1 (55)	
					Naubates fuliginosus 1 (55)	
					Naubates fuliginosus 1 (98)	
					Pseudonirmus gurlti 1 (55)	
					Trabeculus hexacon 1 (55)	
					Trabeculus hexacon 1 (98)	
Procellaria cinerea					*Naubates fuliginosus* 1 (14)	
					Trabeculus hexacon 1 (14)	
					Halipeurus procellariae 1 (14)	
					Halipeurus diversus 1 (14)	
Puffinus griseus					*Halipeurus diversus* 1 (98)	
					Trabeculus hexacon 1 (14)	
					Trabeculus hexacon 1 (98)	
					Naubates prioni 1 (14)	
					Notiopsylla kerguelensis 1 (53)	

Table 1 continued

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
Oceanites oceanicus			*Sarcocystis* sp 3 (27)	*Stegophorus heardi* 1 (8)	*Glaciopsyllus antarcticus* 4 (48)	
					Zachvatkinia stercorarii 4 (63)	
					Philoceanus robertsi 2 (69)	
Pelecanoides georgicus				*Stegophorus heardi* 1 (8)	*Zachvatkinia* sp 1 (68)	
				Stegophorus heardi 1 (70)	*Pelmatocerandra setosa* 1 (98)	
				Tetrabothrius sp 1 (70)	*Pelmatocerandra enderleini* 1 (98)	
Pelecanoides urinatrix				*Stegophorus heardi* 1 (70)	*Pelmatocerandra setosa* 1 (14)	
				Tetrabothrius sp 1 (70)	*Pelmatocerandra setosa* 1 (98)	
					Austromenopon elliotti 1 (98)	
Phalacrocorax atriceps	*Campylobacter lari* I 3 (23)			*Desmidocercella australis* 1 (8)	*Scutomegninia subantarctica* 1 (73)	
	***Salmonella sp* I 3 (23)**			*Tetrabothrius shinni* 3 (71)	*Piagetiella caputincisa* 1 (98)	
	***Yersinia sp* I 3 (23)**			*Corynosoma hamanni* 3 (71)	*Pectinopygus turbinatus* 1 (98)	
	***Campylobacter jejuni* I 3 (23)**			*Corynosoma singularis* 3 (71)		
				Corynosoma bullosum 3 (71)		
				Corynosoma pseudohamanni 2 (72)		
Phalacrocorax albiventer					*Ixodes uriae* 1 (53)	
Phalacrocorax purpurascens					*Pectinopygus turbinatus* 1 (14)	
Chionis alba	*Campylobacter lari* I 2 (23)		*Sarcocystis* sp 3 (27)	*Gymnophallus deliciosus* 1 (74)	*Quadraceps antarcticus* 1 (83)	
	***Salmonella sp* I 2 (23)**			*Gymnophalus deliciosus* 1 (70)	*Quadraceps antarcticus* 1 (98)	
	***Yersinia sp* I 2 (23)**			*Gymnophallus deliciosus* 1 (78)	*Actornithophilus pauliani* 1 (83)	
	***Campylobacter jejuni* I 2 (23)**			*Notocotylus chionis* 1 (74)	*Saemundssonia* sp 1 (83)	
				Notocotylus chionis 1 (70)	Analgesid mites 1 (78)	
				Notocotylus chionis 1 (78)		
				Paramonostomum signiensis 1 (70)		
				Paramonostomum signiensis 1 (77)		
				Lateriporus australis 1 (75)		
				Lateriporus australis 1 (70)		
				Lateriporus australis 1 (78)		
				Nototaenia fileri 1 (75)		
				Nototaenia fileri 1 (78)		

Table 1 continued

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
				Paracuaria tridentata 1 (76)		
				Paracuaria tridentata 1 (78)		
				Phocanema decipiens 1 (76)		
				Phocanema decipiens 1 (78)		
				Contracaecum sp 1 (76)		
				Contracaecum sp 1 (78)		
				Corynosoma hamanni 1 (70)		
				Corynosoma hamanni 1 (76)		
				Corynosoma hamanni 1 (78)		
				Notocotylus chionis 2 (79)		
				Stegophorus macronectes 2 (47)		
				Gymnophallus deliciosus 2 (80)		
				Paramonostomum antarcticum 2 (80)		
				Parorchis acanthus 2 (80)		
				Profilicollis antarcticus 2 (81)		
				Corynosoma hamanni 3 (33)		
				Gymnophallus deliciosus 3 (82)		
Catharacta lonnbergi	*Chlamydophila abortus* I 1 (84)			*Stegophorus arctowski* 2 (47)	*Ixodes uriae* 1 (53)	*Thelebolus microsporus* 3 (87)
	Campylobacter lari I 2 (23)			*Tetrabothrius cylindraceus* 2 (101)	*Austromenopon fuscofasciatum* 1 (14)	
	Alcaligenes faecalis I 2 (21)				*Haffneria grandis* 1 (14)	
	Escherichia coli I 2 (21)				*Saemundssonia euryrhyncha* 1 (14)	
	Micrococcus varians I 2 (21)					
	Micrococcus luteus I 2 (21)					
	Eubacterium alactolyticum I 2 (21)					
	Staphylococcus epidermis I 2 (21)					
	Enterococcus faecalis I 2 (21)					

Table 1 continued

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
	Streptococcus sp I 2 (21)					
	Proteus sp I 2 (21)					
	Pseudomonas sp I 2 (85)					
	Acinetobacter sp I 2 (85)					
	Micrococcus sp I 2 (85)					
	Staphylococcus epidermis I 2 (85)					
	Pasteurella multocida I 2 (85)					
	Pseudomonas pseudomallei I 2 (85)					
	Salmonella sp I 2 (85)					
	Erysipelothrix sp I 2 (85)					
	***Salmonella sp* I 2 (23)**					
	***Yersinia sp* I 2 (23)**					
	***Campylobacter jejuni* I 2 (23)**					
	Campylobacter lari I 3 (35)					
	Pasteurella multocida I 3 (86)					
	Pasteurella multocida I 3 (36)					
	Escherichia coli I 3 (100)					
Catharacta maccormicki	*Campylobacter lari* I 2 (23)	Influenza A 4 (41)	*Coccidia* sp 4 (46)	*Gymnophallus deliciosus* 3 (82)	***Glaciopsyllus antarcticus* 4 (48)**	*Thelebolus microsporus* 3 (87)
	Salmonella sp I 4 (38)	Influenza A 4 (88)	*Sarcocystis* sp 3 (27)	*Corynosoma hamanni* 3 (33)	*Alloptes stercorarii* 4 (63)	*Reighardia sternae* 3 (92)
	***Salmonella sp* I 2 (23)**	Paramyxovirus A 4 (41)	**Blood parasites 2 (90)**	*Renicola williamsi* 4 (89)	*Alloptes catharacti* 4 (68)	
	***Yersinia sp* I 2 (23)**	Infectious Bursal Disease A 4 (88)			*Zachvatkinia stercorarii* 4 (63)	
	***Campylobacter jejuni* I 2 (23)**	NewCastle Disease A 4 (88)				
		Flavivirus A 4 (88)				
		Egg Drop Syndrome A 4 (88)				

Table 1 continued

Species	Bacteria	Virus	Protozoa	Gastro-intestinal Parasites	Ectoparasites	Fungus and others
Catharacta sp		Influenza A 2 (24)			*Austromenopon fuscofasciatum* 1 (98)	
		Influenza A 3 (24)			*Haffneria grandis* 1 (98)	
					Saemundssonia stresemanni 1 (98)	
Larus dominicanus	*Campylobacter lari* I 3 (35)		*Sarcocystis* sp 3 (27)	*Microsomacanthus shetlandicus* 2 (93)	*Notiopsylla kerguelensis* 1 (53)	
	Pasteurella multocida I 3 (36)			*Alcataenia dominicana* 2 (30)	*Actornithophilus piceus lari* 1 (14)	
				Gymnophallus deliciosus 2 (80)	*Quadraceps ornatus* 1 (14)	
				Diplostomum minutum 2 (80)	*Quadraceps ornatus* 1 (98)	
				Diplostomum antarcticum 2 (79)	*Saemundssonia lari* 1 (14)	
				Diplostomum dominicanum 2 (79)	*Saemundssonia lari* 1 (98)	
				Hymenolepis arctowski 2 (94)	*Naubates prioni* 1 (14)	
				Anomotaenia dominicana 2 (95)		*Reighardia sternae* 3 (92)
				Paramonostomum antarcticum 2 (64)		
				Paramonostomum antarcticum 2 (79)		
				Corynosoma shackletoni 2 (96)		
				Corynosoma shackletoni 2 (80)		
				Corynosoma hamanni 3 (33)		
				Gymnophallus deliciosus 3 (82)		
				Eulimdana rauschorum 3 (97)		
Sterna vittata			*Sarcocystis* sp 3 (27)		*Quadraceps houri* 1 (14)	
					Saemundssonia lockleyi 1 (14)	
					Saemundssonia lockleyi 1 (98)	

A Antibodies, *I* isolated, *1* subAntarctic, *2* South Shetlands, *3* Antarctic Peninsula, *4* continental Antarctica. Names in bold denotes absent. Numbers in brackets refers to references in table foot

References: (1) Gauthier-Clerc et al. (1999), (2) Gauthier-Clerc et al. (2002), (3) Morgan et al. (1981), (4) Alexander et al. (1989), (5) Graczyk et al. (1995), (6) Jones (1988) (7) Prudhoe (1969), (8) Mawson (1953), (9) Gauthier-Clerc et al. (1998), (10) Frenot et al. (2001), (11) Mangin et al. (2003), (12) Murray et al. (1991), (13) Banks et al. (2006), (14) Palma and Horning (2002), (15) Cameron (1968), (16) Gardner et al. (1997), (17) Moore and Cameron (1969), (18) Olsen et al. (1996), (19) Palmgrem et al. (2000), (20) Chastel et al. (1993), (21) Jorge et al. (2002), (22) Margni et al. (1967), (23) Bonnedahl et al. (2005), (24) Baumeister et al. (2004), (25) Golemansky (2003), (26) Fredes et al. (2008), (27) Ippen and Henne (1989), (28) Cielecka et al. (1992), (29) Ippen et al. (1981), (30) Georgiev et al. (1996), (31) Fredes et al. (2006), (32) Fredes et al. (2007b), (33) Hoberg (1986a), (34) De Meillon (1952), (35) Leotta et al. (2006a), (36) Leotta et al. (2006b), (37) Nievas et al. (2007), (38) Oelke and Steiniger (1973), (39) Wallensten et al. (2006), (40) MacDonald and Conroy (1971), (41) Austin and Webster (1993), (42) Leotta et al. (2001), (43) Morgan and Westbury (1981), (44) Morgan and Westbury (1988), (45) Fredes et al. (2007a), (46) Miller et al. (1993), (47) Zdzitowiecki and Drozdz (1980), (48) Whitehead et al. (1991), (49) Merino et al. (1997), (50) Andersen and Lysfjord (1982), (51) Broman et al. (2000), (52) Bergstrom et al. (1999b), (53) Murray and Vestjens (1967), (54) Peirce and Prince (1980), (55) Zlotorzycka and Modrzejewska (1992), (56) Bergstrom et al. (1999a), (57) Weimerskirch (2004), (58) Wilson (1970), (59) Leotta et al. (2003), (60) Murray et al. (1967), (61) Bell et al. (1988), (62) Rounsevell and Horne (1986), (63) Horne and Rounsevell (1982), (64) Odening (1982b), (65) Brown (1966), (66) Pilgrim (1998), (67) Chastel and Beaucournu (1992), (68) Mironov (1991), (69) Quillfeldt et al. (2004), (70) Williams et al. (1974), (71) Hoberg (1987a), (72) Dimitrova et al. (1996), (73) Mironov (2000), (74) Jones and Williams (1968), (75) Jones and Williams (1967), (76) Jones and Williams (1969a), (77) Jones and Williams (1969b), (78) Howie et al. (1968), (79) Feiler (1986), (80) Zdzitowiecki et al. (1989), (81) Zdzitowiecki (1985), (82) Hoberg (1984), (83) Jones (1963), (84) Herrmann et al. (2000), (85) MacCormack et al. (1998), (86) Parmelee et al. (1979), (87) Leotta et al. (2002), (88) Miller et al. (2008), (89) Munyer and Holloway (1990), (90) Jones et al. (2002), (91) Steele et al. (1997), (92) Hoberg (1987b), (93) Cielecka and Zdzitowiecki (1981), (94) Jarecka and Ostas (1984), (95) Zdzitowiecki and Szelenbaum-Cielecka (1984), (96) Zdzitowiecki (1978), (97) Hoberg (1986b), (98) Clay and Moreby (1970), (99) Shearn-Boschler et al. (2008), (100) Ikonicoff et al. (1981), (101) Odening (1982a) humans (Waldenstrom et al. 2002), and are transmitted by contaminated food or water; *Pasteurella multocida*, responsible for avian cholera, can be transmitted by aerosols (Simensen and Olson 1980) or by contaminated food or water (Botzler 1991); *Escherichia coli,* although generally part of the natural bacterial flora in birds, can become pathogenic in conjunction with other infections (Morishita et al. 1999); *Chlamidya* sp. which is responsible for psittacosis and is transmitted mainly by aerosols, contaminated water, and by blood-suckling ectoparasites (Harkinezhad et al. 2009). Finally, at least five species of *Salmonella* were detected (Table 1). Interestingly, *Salmonella* was not only found in scavenging species, such as skuas and giant petrels, but also in albatrosses and penguins. These bacteria are common inhabitants of the intestinal tract of birds, and are usually the cause of disease only under conditions of stress. Birds contract the bacteria either through direct contact with infected birds or through ingestion of contaminated food or water (Tizard 2004). It is also interesting to note that in some species (i.e., pygoscelis penguins) reported results have been negative not only for *Campylobacter* sp., *Campylobacter jejuni*, but also for *C. lari* and for *Salmonella* in some locations, while in others the bacteria have been detected. This suggests that the distribution of these bacteria could be restricted to specific locations such as the proximity of research stations (Bonnedahl et al. 2005) or that resistance of the host may differ among different populations of the same species. Protozoa detected in Antarctica belong to six genera (Table 1). Two are blood parasites present in sub-Antarctic islands, but absent in Antarctica. This mirrors the presence of suitable vectors for their transmission that are absent in Antarctica (Merino et al. 1997). However, other such as the role of immunocompetence in preventing infection by blood-parasites in marine birds cannot be excluded (Martinez-Abrain et al. 2004). The remaining four genera are coccidian found in the intestinal tract of birds. Note that only one species has been identified, while most could only be identified to genus level because of the failure of the oocysts to sporulate (Golemansky 2003). Antarctic birds host 39 species and four genera not identified as specific gastrointestinal parasites (Table 1). The most frequently recorded species are the cestodes *Parorchites zederi* and *Tetrabothrius pauliani*, the nematode *Stegophorus macronectes*, the acanthocephalan *Corynosoma hamanni*, and the trematoda *Gymnophallus deliciosus*. The cestodes and nematode mainly infect penguin species, as well as sheathbills (*Chionis alba*) and giant petrels (*Macronectes giganteus*). In contrast, acanthocephalan and trematoda mainly infect not only kelp gulls (*Larus dominicanus*) and skuas (*Catharacta lonnbergi* and *C. maccormicki*) but also sheathbills. Infestations by cestodes, nematodes, acanthocephalan, and trematoda are strongly influenced by the foraging habits of the hosts (Hoberg 1996). General foragers would be expected to be infested by more parasites than specialized species. For instance, the bird species infected by the most species of parasites are sheathbills (14 species) and Kelp gulls (12 species), both are generalists. In comparison, species highly specialized in krill (*Euphausia spp*.) like Chinstrap penguins are only infested by four species of gastrointestinal parasites. *Corynosoma* matures in the intestinal tract of mammals and birds; fish and aquatic invertebrates often serve this worm as intermediate hosts. However, since euphausiids are not part of the intermediate hosts of *Corynosoma*, infestation rates are low krill-dependent species like penguins (Muzaffar and Jones 2004).

The most numerous of parasites in Antarctic and sub-Antarctic birds are ectoparasites with 75 species (Table 1). Lice (Phthiraptera) are the most abundant with 66 species, and some very well-represented genera such as *Austrogoniodes* sp., *Docophoroides* sp., *Naubates* sp., *Trabeculus* sp. or *Saemundssonia* sp. Other ectoparasites include the feather mites *Zachvatknia* sp, *Alloptes* sp., and *Scutomegninia* sp., ticks, of the *Ixodes* genus and the endemic Antarctic flea *Glacyopsillus antarcticus*. Finally, only one fungus infection by *Thelebolus microsporus* was reported in skuas, and two by the pentastomid *Reighardia sternae* in skuas and Kelp gulls.

Antarctic and Sub-Antarctic birds host a total of 173 parasites or pathogenic organisms. The most diversified group in terms of number of species is ectoparasites, especially lice. Although most of them seem to be located in the sub-Antarctic region, birds living in continental Antarctica, such as Emperor (*Aptenodytes forsteri*) and Adelie penguins (*Pygoscelis adeliae*) are parasitized by some lice. This suggests that lice are not limited by the environmental conditions of polar environments. However, these harsh conditions seem to limit the diversity and abundance of parasitic protozoa, which are represented by only six genera, specifically blood parasites, as these organisms need an arthropod vector to infect the birds (see above). The second most abundant group is the bacteria, which is clearly correspond to this group's enormous diversity elsewhere. However, little is known about the community of potential pathogenic bacteria present in Antarctic birds (Kerry et al. 1999). The presence of viruses is difficult to evaluate because no disease-causing virus has yet been isolated in Antarctica, although certain virus antibodies have been found (see above). Therefore, more attention must be given to the isolation of pathogenic viruses in Antarctica.

Geographical variation in the distribution of reported parasites, pathogens and diseases shows that 63 of these organisms (eight bacteria, six viruses, two protozoa, 18 gastrointestinal parasites and 29 ectoparasites) are present in sub-Antarctic islands. Sixty organisms (32 bacteria, two viruses, two protoza, 23 gastro-intestinal parasites and one ectoparasite) are present in the South Shetlands and 23 in the continental Antarctic Peninsula (10 bacteria, two virus, two protozoa and nine gastrointestinal parasites). In continental Antarctica, there are 19 parasites or pathogens (two bacteria, four viruses, one protozoon, four gastrointestinal parasites and eight ectoparasites) (Table 1). It is difficult to interpret these apparent differences in distribution from a biological point of view, because they probably reflect differences in research effort in the various Antarctic regions rather than any actual geographical variation. For instance, the largest number of organisms was found at the South Shetlands where also most of the relevant research has been done in Antarctica. However, ectoparasites seem to be more common in the sub-Antarctic islands, which is to be expected from their dependency on thermal conditions. On the other hand, more ectoparasite species have been found in continental Antarctica than in the South Shetlands or the Antarctic Peninsula, which is contrary to expectations from a biological point of view. These results probably reflect the differential attention paid to this group in these regions. The distribution of bacteria also supports this idea.

To determine the actual distribution of these organisms the absence of parasites or pathogens in Antarctica must be considered as well. However, only nine out of 98 studies reported negative findings (i.e., Merino et al. 1997, Bonnedahl et al. 2005). This kind of information is as important as positive findings as it may aid to establish the time they may have been present, to determine the causes of their presence and to evaluate their impact on Antarctic fauna. To obtain the required information sample sizes have to be sufficiently large for results to be reliable (Bonnedahl et al. 2005). The techniques used to detect the pathogens are also important, as in some cases the presence of these organisms is extrapolated from serological methods (i.e., Gardner et al. 1997). The presence of antibodies suggests the exposure to a pathogen, but does not necessarily indicate its presence in that particular place, because the contact may have occurred elsewhere or in a particular time because the organisms may not always be present. This is especially important in migratory species such as skuas, gulls or terns. Moreover, it may indicate only the presence of a serologically related nonpathogenic organism (Kerry et al. 1999). Even given how little is known about endemic pathogen it is possible that our available test react with similar but as yet unknown organisms. Therefore, the presence of pathogenic organisms inferred from antibodies in either species or location should be taken with caution, and studies addressing their isolation should be encouraged.

The effects of parasites in Antarctic birds have been studied little. *Ixodes uriae* has attracted more attention than any other parasite (Gauthier-Clerc et al. 1998; Bergstrom et al. 1999a, b; Mangin et al. 2003 among others). In general, ticks may be causing delayed growth (Moreby 1996) and mortality in chicks (Bergstrom et al. 1999a), affecting the host population dynamics (Boulinier and Danchin 1996). Other parasites have been given less attention, and studies dealing with the effects of parasites may be considered almost anecdotic (e.g., Quillfeldt et al. 2004 for effects of chewing lice on physiology). Therefore, because of the lack of studies, the probable effects of parasites on Antarctic avifauna must be extrapolated from information taken in other organisms or in other latitudes, reducing its reliability. Therefore, further studies are required to shed light on the situation.

Another gap in the information reviewed is that most of the publications only provide descriptive data about the presence of the parasites, pathogens or diseases, and only a few give information on the prevalence and/or intensity of parasitism. Only 16 out of 101 papers reviewed focused on physiology related to parasitism or diseases, and most of these were in penguins.

Thus, it may be concluded that the information published about diseases and parasites in Antarctic birds is scarce and fragmental. Moreover, some studies were undertaken at least 20 years ago and in others pathogens were detected through traditional techniques, which are less reliable than modern molecular methods. Overall little is known about which diseases are endemic or exotic. Knowledge about the presence of disease and parasites is crucial to understand how Antarctica is functioning in terms of ecosystem health. This information is important to the decision-making process in conservation management. The possibility that emergent infectious diseases could cause a catastrophic extinction of bird populations is a plausible scenario (Van Riper et al. 1986) although there is only one documented case of extinction by infection (Daszak and Cunningham 1999). Antarctica is not beyond this risk, animals affected by new pathogens or parasites can be severely affected due to their less effective immunological systems (Merino et al. 2001). Moreover, the presence of pollutants in the environment can depress the immune system, increasing the magnitude of such effects (Briggs et al. 1997). As infestation by a great number of parasites, like gastrointestinal parasites, is dependent on feeding habits (Hoberg 1996), changes in prey can play an important role in exposure to new parasites. Changes in diet may be a consequence of climate change (Emslie et al. 1998) or overexploitation of krill. We, therefore, need to improve our knowledge of physiological functions, such as the immune system, to understand the biological basis for disease and the effects of parasites.

Another point of critical importance concerning disease in Antarctica is related to public health. Most human emergent infectious diseases are acquired from exposure to pathogens transmitted naturally between animals and humans, that is, by zoonotic transmission and wildlife play a key role by providing reservoirs to unknown pathogens responsible for such diseases (Daszak et al. 2000). Although Antarctica can still be considered an isolated continent, the presence of thousands of people each austral summer could increase the risk of zoonosis, although only a small part of those people have close contact with Antarctic birds or mammals. Influenza, caused by a virus, and Lyme disease, caused by the bacteria *Borrelia burgdorferi,* are two examples of this kind of potential zoonotic disease.

Finally, Kerry et al. (1999) made several recommendations for reducing the risk of humans introducing disease in Antarctica. These included setting up a "central clearinghouse for information on suspected disease occurrences" (Recommendation 4) and "establishment of serum banks" (Recommendation 19). However, 10 years after their presentation to the Antarctic Treaty, to our knowledge, such recommendations have not yet been implemented. Specifically, these two recommendations must be complied with to improve our knowledge about the health of bird and mammals populations in Antarctica to help prevent outbreaks or make decisions when they occur.

Acknowledgments This review was done under International Polar Year Project number 172 Birdhealth. This study was supported by Projects CGL2004-01348 and POL2006-05175 funded by the Spanish Ministry of Science and Innovation and by the European Regional Development Fund. MJP was supported by a Ph.D. grant from the Spanish Ministry of Science and Innovation (BES-2005-8465). We specially thank Barbara Wienecke and two anonymous referees for helpful suggestions on an early version of this manuscript. Deborah Faldauer corrected the language.

References

Alexander DJ, Manvell RJ, Collins Ms, Brockman SJ, Westbury HA, Morgan I, Austin FJ (1989) Characterization of paramyxoviruses isolated from penguins in Antarctica and Sub-Antarctica during 1976–1979. Arch Virol 109:135–143. doi:10.1007/BF01310525

Andersen KI, Lysfjord S (1982) The functional morphology of the scolex of two Tetrabothrius Rudolphi 1819 species (Cestoda: Tetrabothriidae) from penguins. Parasitol Res 67:299–307

Austin FJ, Webster RG (1993) Evidence of ortho- and paramyxoviruses in fauna from Antarctica. J Wildl Dis 29:568–571

Banks JC, Palma RL, Paterson AM (2006) Cophylogenetic relationships between penguins and their chewing lice. J Evol Biol 19:156–166. doi:10.1111/j.1420-9101.2005.00983.x

Baumeister E, Leotta G, Pontoriero A, Campos A, Montalti D, Vigo G, Pecoraro M, Savy V (2004) Serological evidences of influenza A virus infection in Antarctica migratory birds. Int Congr Ser 1263:737–740. doi:10.1016/j.ics.2004.02.099

Bell PJ, Burton HR, van Franeker JA (1988) Aspects of the biology of *Glaciopsyllus antarcticus* (Siphonaptera: Ceratophyllidae) during the breeding season of a host (*Fulmarus glacialoides*). Polar Biol 8:403–410. doi:10.1007/BF00264716

Bergstrom S, Haemig PD, Olsen B (1999a) Increase mortality of black-browed albatross chicks at a colony heavily-infested with the tick *Ixodes uriae*. Int J Parasitol 29:1359–1361. doi:10.1016/S0020-7519(99)00088-0

Bergstrom S, Haemig PD, Olsen B (1999b) Distribution and abundance of the tick *Ixodes uriae* in a diverse subantarctic community. J Parasitol 85:25–27. doi:10.2307/3285694

Bonnedahl J, Broman T, Waldenström J, Palmgren H, Niskanen T, Olsen B (2005) In search of human-associated bacterial pathogens in Antarctic wildlife: report from six penguin colonies regularly visited by tourists. Ambio 34:430–432

Botzler RG (1991) Epizootiology of avian cholera in wild fowl. J Wildl Dis 27:367–395

Boulinier T, Danchin E (1996) Population trends in kittiwake *Rissa tridactyla* colonies in relation to tick infestation. Ibis 138:326–334. doi:10.1111/j.1474-919X.1996.tb04345.x

Briggs KT, Gershwin E, Anderson DW (1997) Consequences of petrochemical ingestion and stress on the immune system of seabirds. ICES J Mar Sci 54:718–725. doi:10.1006/jmsc.1997.0254

Broman T, Bergstrom S, On SLW, Palmgren H, McCafferty DJ, Sellin M, Olsen B (2000) Isolation and characterization of *Campylobacter jejuni subsp jejuni* from macaroni penguins (*Eudyptes chrysolophus*) in the subantarctic region. Appl Environ Microbiol 66:449–452

Brown DA (1966) Breeding biology of the Snow Petrel *Pagodroma nivea* (Forster) ANARE (Aust Nat Antarct Res Exp). Sci Rep Ser B 89:1–63

Cameron AS (1968) The isolation of a psittacosis-lymphogranuloma venerium (PL) agent from an emperor penguin (*Aptenodytes forsteri*) chick. Aust J Exp Biol Med Sci 46:647–649. doi:10.1038/icb.1968.172

Chastel O, Beaucournu JC (1992) Notes sur la specificite et l'eco-ethologie des puces d'oiseaux aux Iles Kerguelen (Insecta; Siphonaptera). Ann Parasitol Hum Comp 67:213–220

Chastel C, Demazure M, Chastel O, Genevois F, Legrand MC, Gralet O, Odernatt M, Legoff F (1993) A rickettsia-like organism from *Ixodes uriae* ticks collected on the Kerguelen Islands (French sub-Antarctic territories). Acta Virol 37:11–20

Cielecka D, Zdzitowiecki K (1981) The tapeworm *Microsomacanthus shetlandicus* sp. n. (Hymenolepididae) from the Dominican gull of King George Island (South Shetlands, Antarctic). Bull Acad Pol Sci Biol 29:173–180

Cielecka D, Wojciechowska A, Zdzitowiecki K (1992) Cestodes from penguins on King George Island (South Shetlands, Antarctic). Acta Parasitol 37:65–72

Clarke J, Kerry K (2000) Diseases and parasites of penguin. Penguin Conserv 13:5–24

Clay T, Moreby C (1970) Mallophaga and Anoplura of Subantarctic islands. Pac Insect Monogr 23:216–220

Curry CH, McCarthy JS, Darragh HM, Wake RA, Todhunter R, Terris J (2002) Could tourist boots act as vectors for disease transmission in Antarctica? J Travel Med 9:190–193

Daszak P, Cunningham AA (1999) Extinction by infection. Trends Ecol Evol 14:279. doi:10.1016/S0169-5347(99)01665-1

Daszak P, Cunningham AA, Hyatt AD (2000) Emerging infectious diseases of wildlife: threats to biodiversity and human health. Science 287:443–449. doi:10.1126/science.287.5452.443

De Meillon B (1952) The fleas of seabirds in the Southern Ocean. ANARE Report Series B, vol 1. Zoology

Dimitrova ZM, Chipev NH, Georgiev BB (1996) Record of *Corynosoma pseudohamanni* Zdzitowiecki, 1984 (Acanthocephala, Polymorphidae) in birds at Livingston Island, South Shetlands, with a review of Antarctic avian acanthocephalans. Bulg Antarct Res Life Sci 1:102–110

Emslie S, Fraser W, Smith RC, Walder W (1998) Abandoned penguin colonies and environmental change in the Palmer Station area, Anvers Island, Antarctic Peninsula. Antarct Sci 10:257–268. doi:10.1017/S0954102098000352

Epstein PR, Chivian E, Frith K (2003) Emerging diseases threaten conservation. Environ Health Perspect 111:A506–A507

Feiler K (1986) Trematoden aus *Chionis alba* und *Larus dominicanus* von den Süd-Shetland-Inseln (Antarktis). Angew Parasitol 27:23–33

Fredes F, Raffo E, Muñoz P, Herrera M (2006) Fauna parasitaria gastrointestinal en polluelos de Pingüino papua (*Pygoscelis papua*) encontrados muertos en zona antártica especialmente protegida (ZAEP N° 150). Parasitol Latinoam 61:179–182

Fredes F, Raffo E, Muñoz P (2007a) First report of *Cryptosporidium* spp. Oocysts in stool of Adelie penguin from the Antarctic using acid-fast stain. Antarct Sci 19:437–438

Fredes F, Madariaga C, Raffo E, Valencia J, Herrera M, Godoy C, Alcaino H (2007b) Gastrointestinal parasite fauna of gentoo penguins (*Pygoscelis papua*) from the Peninsula Munita, Bahía Paraiso, Antarctica. Antarct Sci 19:93–94

Fredes F, Diaz A, Raffo E, Muñoz P (2008) *Cryptosporidium* spp. Oocysts detected using acid-fast stain in faeces of gentoo penguins (*Pygoscelis papua*) in Antarctica. Antarct Sci 20:495–496. doi:10.1017/S0954102008001296

Frenot Y, de Oliveria E, Gauthier-Clerc M, Dennff J, Bellido A, Vernon P (2001) Life cycle of the tick *Ixodes uriae* in penguin colonies: relationships with host breeding activity. Int J Parasitol 31:1040–1047. doi:10.1016/S0020-7519(01)00232-6

Frenot Y, Chown SL, Whinam J, Selkirk PM, Convey P, Skotnicki M, Bergstrom DM (2005) Biological invasions in the Antarctic: extent, impacts and implications. Biol Rev Camb Philos Soc 80:45–72. doi:10.1017/S1464793104006542

Friend M (2006) Evolving changes in diseases of waterbirds. In: Boere GC, Galbraith CA, Stroud DA (eds) Waterbirds around the world. The Stationery Office, Edinburgh, pp 412–417

Gardner H, Kerry K, Riddle M, Brouwer S, Gleeson L (1997) Poultry virus infection in Antarctic penguins. Nature 387:245. doi:10.1038/387245a0

Gauthier-Clerc M, Clerguin Y, Handrich Y (1998) Hyperinfestation by ticks *Ixodes uriae*: a possible cause of death in adult king penguins, a long-lived seabird. Colon Waterbirds 21:229–233. doi:10.2307/1521910

Gauthier-Clerc M, Jaulhac B, Frenot Y, Bachelard C, Monteil H, Le Maho Y, Handrich Y (1999) Prevalence of *Borrelia burgdorferi* (the Lyme disease angent) antibodies in king penguin *Aptenodytes patagonicus* in Crozet Archipielago. Polar Biol 22:141–143. doi:10.1007/s003000050402

Gauthier-Clerc M, Eterradossi N, Toquin D, Guittet M, Kuntz G, Le Maho Y (2002) Serological survey of the king penguin *Aptenodytes patagonicus*, in Crozet archipielago for antibodies to infectious bursal disease influenza A and Newcastle disease virus. Polar Biol 25:316–319

Georgiev BB, Vasileva GP, Chipev NH, Dimitrova ZM (1996) Cestodes of seabirds at Livingston Island, South Shetlands. Bulg Antarct Res Life Sci 1:111–127

Golemansky V (2003) *Eimeria pygosceli* n. sp. (Coccidia: Eimeriidae) from the penguins (Pygoscelidae) of the Livingston Island (the Antarctic). Acta Zool Bulg 55:3–8

Graczyk TK, Cranfield MR, Brossy JJ, Cockrem JF, Jouventin P, Seddon PJ (1995) Detection of avian malaria infections in wild and captive penguins. J Helmitol Soc Wash 62:135–141

Grenfell BT, Dobson AP (1995) Ecology of infection diseases in natural populations. Cambridge University Press, Cambridge

Haldane JBS (1949) Disease and evolution. Ric Sci Suppl A 19:68–76

Harkinezhad T, Geens T, Vanrompay D (2009) *Chlamydophila psittaci* infections in birds: a review with emphasis on zoonotic consequences. Vet Microbiol 135:68–77. doi:10.1016/j.vetmic.2008.09.046

Harvell CD, Mitchell CE, Ward JR, Altizer S, Dobson AP, Ostfeld RS, Samuel MD (2002) Climate warming and disease risks for terrestrial and marine biota. Science 296:2158–2163. doi:10.1126/science.1063699

Herrmann B, Rahman R, Bergstrom S, Bonnedahl J, Olsen B (2000) *Chlamydophila abortus* in a Brown Skua (*Catharacta antarctica lonnbergi*) from a subantarctic island. Appl Environ Microbiol 66:3654–3656. doi:10.1128/AEM.66.8.3654-3656.2000

Hillgarth N, Wingfield JC (1997) Parasite-mediated sexual selection: endocrine aspects. In: Clayton DH, Moore J (eds) Host-parasite evolution. General principles and avian models. Oxford University Press, Oxford, pp 78–104

Hoberg EP (1984) Trematode parasites of marine birds in Antarctica: the distribution of *Gymnophallus deliciosus* (Olsson 1893). Antarct J US 19:159–160

Hoberg EP (1986a) Aspects of ecology and biogeography of Acantocephala in Antarctic seabirds. Ann Parasitol Hum Comp 61:199–214

Hoberg EP (1986b) *Eulindana rauschorum* n. sp. a filarioid nematode (Lemdaninae) from *Larus dominicanus* in Antarctica with comments on evolution and biogeography. J Parasitol 72:755–761. doi:10.2307/3281469

Hoberg EP (1987a) *Tetrabothrius shinni* sp. nov. (Eucestoda) from *Phalacrocorax atriceps bransfieldensis* (Pelecaniformes) in Antarctica with comments on morphological variation host-parasite biogeography and evolution. Can J Zool 65:2969–2975. doi:10.1139/z87-450

Hoberg EP (1987b) *Reighardia sternae* (Diesing, 1864) from seabirds in Antarctica. Can J Zool 65:1289–1291. doi:10.1139/z87-203

Hoberg EP (1996) Faunal diversity among avian parasite assemblages: the interaction of history, ecology and biogeography in marine systems. Bull Scand Soc Parasitol 6:65–89

Hochachka WM, Dhondt AA (2000) Density-dependent decline of host abundance resulting from a new infectious disease. Proc Natl Acad USA 97:5303–5306. doi:10.1073/pnas.080551197

Horne PA, Rounsevell D (1982) A Collection of feather mites (Acari: Astigmata) from Greater (Eastern) Antarctica. Pac Insects 24:196–197

Howie CA, Jones NV, Williams IC (1968) A report on the death of sheathbills *Chionis alba* (Gmelin) at Signy Island, South Orkney Islands during the winter of 1965. Br Antarct Surv Bull 18:79–83

Hubalek Z (2004) An annotated checklist of pathogenic microorganisms associated with migratory birds. J Wildl Dis 40:639–659

Ikonicoff S, Zunino CH, Castrelos OD, Margni RA (1981) Microbiología antártica: nuevos estudios efectuados en Bahía Esperanza. Contrib Cient Inst Antart Argent 362:1–19

IPCC (2007) Climate Change 2007: The physical science basis. Contribution of working group I to the fourth assessment report of the IPCC. In: Solomon S, Qin D, Manning M, Chen Z, Marguis M, Averyt K, Tignor MMB, Miler Jr HL (eds) Cambridge University Press for the Intergovernmental Pannel of Climate Change, Cambridge

Ippen R, Henne D (1989) Weitere Sarcocystisbefunde bei Vogeln und Saugetieren der Antarktis. Erkrg Zootiere 31:371–376

Ippen R, Odening K, Henne D (1981) Cestode *Parorchites zederi* and sarcosporidian *Sarcocystis* spp. Infections in penguins of the South Shetland Islands. Erkrg Zootiere 22:203–210

Jarecka L, Ostas J (1984) *Hymenolepis arctowskii* sp. n. (Cestoda, Hymenolepididae) from *Larus dominicanus* Licht. of the Antarctic. Acta Parasitol Pol 29:189–196

Jensen T, Van de Bildt M, Dietz HH, Andersen TH, Hammer AS, Kuiken T, Osterhaus A (2002) Another phocine distemper outbreak in Europe. Science 297:209. doi:10.1126/science.1075343

Jones NV (1963) The sheathbill *Chionis alba* (Gmelin) at Signy Island, South Orkney Islands. Br Antarct Surv Bull 2:53–71
Jones HI (1988) Notes on parasites in penguins (Spheniscidae) and petrels (Procellariidae) in the Antarctic and sub-Antarctic. J Wildl Dis 24:166–167
Jones NV, Williams IC (1967) The cestode parasites of the sheathbill *Chionis alba* (Gmelin) from Signy Island, South Orkney Islands. J Helminthol 41:151–160
Jones NV, Williams IC (1968) The trematode parasites of the sheathbill *Chionis alba* (Gmelin) from Signy Island, South Orkney Islands. J Helminthol 42:65–80
Jones NV, Williams IC (1969a) The nematode and acanthocephalan parasites of sheathbill, *Chionis alba* (Gmelin) at Signy Island, South Orkney Islands and a summary of host parasite relationships in the sheathbill. J Helminthol 43:59–67
Jones NV, Williams IC (1969b) *Paramonostomum signiensis* n. sp. (Trematoda: Notocotylidae) from the sheathbill *Chionis alba*. J Helminthol 43:53–57
Jones HI, Gallagher JM, Miller GD (2002) Survey of South Polar Skuas (*Catharacta maccormicki*) for blood parasites in the Vestfold Hills region of Antarctica. J Wildl Dis 38:213–215
Jorge MC, Najle R, Montalti D (2002) Cloacal bacterial flora on Antarctic birds. Riv Ital Orn 71:163–169
Kerry K, Riddle M, Clarke K (1999) Diseases of Antarctic wildlife. A report for SCAR and COMNAP. SCAR
Laurance WF, McDonald KR, Speare R (1996) Epidemic disease and the catastrophic decline of Australian rain forest frogs. Conserv Biol 10:406–413. doi:10.1046/j.1523-1739.1996.10020406.x
Leotta GA, Cerda R, Coria NR, Montalti D (2001) Preliminary studies on some avian diseases in Antarctic birds. Pol Polar Res 22:227–231
Leotta GA, Pare JA, Sigler L, Montalti D, Vigo G, Petruccelli M, Reinoso EH (2002) *Thelebolus microsporus* mycelial mats in the trachea of wild brown skua (*Catharacta antarctica lonnbergi*) and south polar skua (*C. maccormicki*) carcasses. J Wildl Dis 38:443–447
Leotta GA, Rivas M, Chinen I, Vigo GB, Moredo FA, Coria N, Wolcott MJ (2003) Avian cholera in a southern giant petrel (*Macronectes giganteus*) from Antarctica. J Wildl Dis 39:732–735
Leotta GA, Vigo GB, Giacoboni G (2006a) Isolation of *Campylobacter lari* from seabirds in Hope Bay, Antarctica. Pol Polar Res 27:303–308
Leotta GA, Chinen I, Vigo GB, Pecoraro M, Rivas M (2006b) Outbreaks of avian cholera in Hope Bay, Antarctica. J Wildl Dis 42:259–270
MacCormack WP, Vazquez SC, Montalti D (1998) Studies on the bacterial flora associated to the brown skua (*Catharacta antarctica lonnbergi*). Ber z. Polarforschung 299:182–185
MacDonald DM, Conroy JWH (1971) Virus disease resembling puffinosis in the gentoo penguin (*Pygoscelis papua*). Br Antarct Surv Bull 60:80–83
Mangin S, Gauthier-Clerc M, Frenot Y, Gendner JP, Le Maho Y (2003) Ticks *Ixodes uriae* and the breeding performance of a colonial seabird, King penguin *Aptenodytes patagonicus*. J Avian Biol 34:30–34. doi:10.1034/j.1600-048X.2003.02916.x
Margni RA, Castrelos OD, Herrera ME (1967) Estudios bacteriológicos del contenido gastrointestinal y cloacal de pingüinos antárticos. Contrib Cient Inst Antart Argent 102:1–19
Martinez-Abrain A, Esparza B, Oro D (2004) Lack of blood parasites in bird species: absence of blood parasite vector explain it all? Ardeola 51:225–232
Mawson PM (1953) Parasitic nematoda collected by the Australian National Antarctic Research Expedition: Heard Island and Macquarie Island 1948–1951. Parasitology 43:291–297
Merino S, Barbosa A, Moreno J, Potti J (1997) Absence of haematozoa in a wild chinstrap penguin *Pygoscelis antarctica* population. Polar Biol 18:227–228. doi:10.1007/s003000050181
Merino S, Martinez J, Møller AP, Barbosa A, de Lope F, Rodriguez-Caabeiro F (2001) Physiological and hematological consequences of a novel parasite on the red-rumped swallow Hirundo rustica. Int J Parasitol 31:1187–1193. doi:10.1016/S0020-7519(01)00243-0
Miller GD, Couch L, Duszynski DW (1993) Preliminary survey for coccidian parasites in the birds of Cape Bird, Ross Island. Antarct J US 28:148
Miller GD, Watts JM, Shellam GR (2008) Viral antibodies in South Polar Skuas around Davis Station, Antarctica. Antarct Sci 20:455–461. doi:10.1017/S0954102008001259
Mironov SV (1991) Two new species of the feather mites superfamily Analgoidea from the Antarctic birds. Inf Byull Sov Antarkt Eksped 116:69–75
Mironov SV (2000) A review of the feather mite genus *Scutomegninia* Dubinin, 1951 (Acarina: Analgoidea: Avenzoariidae). Acarina 8:9–58
Møller AP (1997) Parasitism and the evolution of host life history. In: Clayton DH, Moore J (eds) Host-parasite evolution. General principles and avian models. Oxford University Press, Oxford, pp 105–127
Møller AP, De Lope F, Moreno J, Gonzalez G, Perez JJ (1994) Ectoparasites and host energetics: house martin bugs and house martin nestlings. Oecologia 98:263–268. doi:10.1007/BF00324213
Moore BW, Cameron AS (1969) Chlamydia antibodies in Antarctic fauna. Avian Dis 13:681–684. doi:10.2307/1588545
Moreby YE (1996) The abundance and effects of ticks (*Ixodes uriae*) on nestling Cassin's auklets (*Ptychorramphus aleuticus*) at Triangle island, British Columbia. Can J Zool 74:1585–1589. doi:10.1139/z96-172
Morgan IR, Westbury HA (1981) Virological studies of Adelie penguin (*Pygoscelis adeliae*) in Antarctica. Avian Dis 25:1019–1026. doi:10.2307/1590077
Morgan IR, Westbury AS (1988) Studies of viruses in penguins in the Vestfold Hills. Hydrobiologia 165:263–269. doi:10.1007/BF00025595
Morgan IR, Westbury HA, Caple IW, Campbell J (1981) A survey of virus infection in sub-Antarctic penguins on Macquarie Island, Southern Ocean. Aust Vet J 57:333–335. doi:10.1111/j.1751-0813.1981.tb05839.x
Morishita TY, Aye PP, Ley EC, Harr BC (1999) Survey of pathogens and blood parasites in free-living passerines. Avian Dis 43:549–552. doi:10.2307/1592655
Munyer PD, Holloway HL Jr (1990) *Renicola williamsi* n. sp. (Trematoda: Digenea: Renicolidae) from the south Polar skua, *Catharacta maccormiki*. Trans Am Microsc Soc 109:98–102. doi:10.2307/3226600
Murray MD, Vestjens WJM (1967) Studies on the ectoparasites of seals and penguins. Aust J Zool 15:715–725. doi:10.1071/ZO9670715
Murray MD, Orton MN, Cameron AS (1967) The Antarctic Flea *Glaciopsyllus antarctica* Smit and Dunnet. Antarct Res Ser 10:393–395
Murray MD, Palma RL, Pilgrim RLC (1991) Ectoparasites of Australian, New Zealand and Antarctic birds. Appendix I. In: Marchant S, Higgins PJ (eds) Handbook of Australian, New Zealand and Antarctic birds, vol I. Part A. Oxford University Press, Melbourne
Muzaffar SB, Jones IL (2004) Parasites and diseases of the auks (alcidae) of the world and their ecology—a review. Mar Ornithol 32:121–146

Nievas VF, Leotta GA, Vigo GB (2007) Subcutaneous clostridial infection in Adelie penguins in Hope Bay, Antarctica. Polar Biol 30:249–252. doi:10.1007/s00300-006-0179-5

Odening K (1982a) Cestoden aus Flugvogeln der Sudshetlands (Antarktis) und der Falklandinseln (Malwinen). Angew Parasitol 23:202–223

Odening K (1982b) *Paramonostomum antarcticum* (Trematoda, Nocotylidae) in Larus dominicanus der Südshetlands (Antarktis). Angew Parasitol 23:137–143

Oelke H, Steiniger F (1973) Salmonella in adelie penguins (*Pygoscelis adeliae*) and south polar skuas (*Catharacta maccormicki*) on Ross Island, Antarctica. Avian Dis 17:568–573. doi:10.2307/1589155

Olsen B, Bergstrom S, McCafferty DJ, Sellin M, Wistrom J (1996) *Salmonella enteriditis* in Antarctica: zoonosis in man or humanosis in penguins. Lancet 348:1319–1320. doi:10.1016/S0140-6736(05)65807-2

Palma RL, Horning DS (2002) The lice (Insecta: Phtiraptera) from Macquaire Island. ANARE Res Notes 148:1–36

Palmgrem H, McCafferty D, Aspan A, Broman T, Sellin M, Wollin R, Bergstrom S, Olsen B (2000) Salmonella in sub-Antarctica: low heterogeneity in Salmonella serotypes in South Georgia seals and birds. Epidemiol Infect 125:262–275

Parmelee DF, Maxson SJ, Berstein NP (1979) Fowl cholera outbreak among brown skuas at Palmer Station. Antarct J US 14:168–169

Peirce MA, Prince PA (1980) *Hepatozoon albatrossi* sp nov. (Eucoccida: Hepatozidae) from Diomedea spp in the Antarctic. J Nat Hist 14:447–452. doi:10.1080/00222938000770381

Pilgrim RLC (1998) Larvae of the genus *Notiopsylla* (Siphonaptera: Pygiopsyllidae) with a key to their identification. J Med Entomol 35:362–376

Prudhoe S (1969) Cestodes from fish, birds and whales. BANZARE Rep Ser B VIII(Part 9)

Quillfeldt P, Masello JF, Moestl E (2004) Blood chemistry in relation to nutrition and ectoparasite load in Wilson's stormpetrels *Oceanites oceanicus*. Polar Biol 27:168–176. doi:10.1007/s00300-003-0572-2

Rapport DJ (2007) Sustainability science: an ecohealth perspective. Sustain Sci 2:77–84. doi:10.1007/s11625-006-0016-3

Rau ME (1983) Establishment and maintenance of behavioural dominance in male mice infected with *Trichinella spiralis*. Parasitology 86:319–322

Rounsevell DE, Horne PA (1986) Terrestrial, parasitic and introduced invertebrates of the Vestfold Hills. In: Pickard J (ed) Antarctic oasis, terrestrial environments and history of the Vestfold Hills. Academic Press, New York, pp 309–331

Shearn-Boschler V, Green DE, Converse KA, Docherty DE, Thiel T, Geisz HN, Fraser WR, Patterson-Fraser DP (2008) Cutaneous and diphtheritic avian poxvirus infection in a nestling Southern Giant Petrel (*Macronectes giganteus*) from Antarctica. Polar Biol 31:569–573. doi:10.1007/s00300-007-0390-z

Shirihai H (2002) A complete guide to Antarctic wildlife. The birds and marine mammals of the Antarctic Continent and Southern Ocean. Alula Press Oy, Finland

Simensen E, Olson LD (1980) Aerosol transmission of *Pasteurella multocida* in turkeys. Avian Dis 24:1007–1010. doi:10.2307/1589975

Steele WK, Pilgrim RLC, Palma RL (1997) Ocurrence of the flea *Glacypsillus antarcticus* and avian lice in central Droming Maud Land. Polar Biol 18:292–294. doi:10.1007/s003000050190

Steig EJ, Schneider DP, Rutherford RD, Mann ME, Comiso JC, Shindell DT (2009) Warming of the Antarctic ice-sheet surface since the 1957 International Geophysical Year. Nature 457:459–463. doi:10.1038/nature07669

Sutherst RW (2001) The vulnerability of animal and human health to parasites under global change. Int J Parasitol 31:933–948. doi:10.1016/S0020-7519(01)00203-X

Tizard I (2004) Salmonellosis in wild birds. Semin Avian Exotic Pet Med 13:50–66. doi:10.1053/j.saep.2004.01.008

Turner J, Sr Colwell, Marshall GJ, Lachlan-Cope TA, Carleton AM, Jones PD, Lagun V, Reid PA, Iagovkina S (2004) The SCAR READER project: toward a high-quality database of mean Antarctic meteorological observations. J Clim 17:2890–2898. doi:10.1175/1520-0442(2004)017<2890:TSRPTA>2.0.CO;2

Van Riper CI, Goff ML, Laird M (1986) The epizootiology and ecological significance of malaria in Hawaiian land birds. Ecol Monogr 56:327–344. doi:10.2307/1942550

Waldenstrom J, Broman T, Carlsson I, Hasselquist D, Achterberg RP, Wanegaar JA, Olse B (2002) Prevalence of *Campylobacter jejuni, Campylobacter lari* and *Campylobacter coli* in different ecological guilds and taxa of migrating birds. Appl Environ Microbiol 68:5911–5917. doi:10.1128/AEM.68.12.5911-5917.2002

Wallensten A, Munster VJ, Osterhaus ADME, Waldenstrom J, Bonnedahl J, Broman T, Fouchier RAM, Olsen B (2006) Mounting evidence for the presence of influenza A virus in the avifauna of the Antarctic region. Antarct Sci 18:353–356. doi:10.1017/S095410200600040X

Weimerskirch H (2004) Diseases threaten Southern Ocean albatrosses. Polar Biol 27:374–379. doi:10.1007/s00300-004-0600-x

Whitehead MD, Burton HR, Bell PJ, Arnould JPY, Rounsevell DE (1991) A further contribution on the biology of the Antarctic flea, *Glaciopsyllus antarcticus* (Siphonaptera: Cerataophyllidae). Polar Biol 11:379–383. doi:10.1007/BF00239690

Williams IC, Jones NV, Payne MJ, Ellis C (1974) The helminth parasites of the sheathbill, *Chionis alba* and the diving petrels, *Pelecanoid georgicus* and *P. urinatrix* at Bird Island, South Georgia. J Helminthol 48:195–197

Wilson N (1970) Acarina: Mesostigmata: Halarachnidae, Rhinonyssidae of South Georgia, Heard and Kerguelen. Pac Insects Monogr 23:71–77

Zdzitowiecki K (1978) *Corynosoma shackletoni* sp. n. from hosts in South Shetlands and South Georgia (Antarctic). Bull Acad Pol Sci Biol 26:629–634

Zdzitowiecki K (1985) Acanthocephalans of birds from South Shetlands (Antarctic). Acta Parasitol Pol 30:11–24

Zdzitowiecki K, Drozdz J (1980) Redescription of *Stegophorus macronectes* (Johnston et Mawson, 1942) and description of *Stegophorus arctowskii* sp. n. (Nematoda, Spirurida) from birds of South Shetlands (the Antarctic). Acta Parasitol Pol 27:205–212

Zdzitowiecki K, Szelenbaum-Cielecka D (1984) *Anomotaenia dominicana* (Railliet et Henry, 1912) (Cestoda, Dilepididae) from the Dominican gull *Larus dominicanus* Licht. of the Antarctic. Acta Parasitol Pol 29:49–58

Zdzitowiecki K, Niewiadomska K, Drozdz J (1989) Trematodes of birds and mammals in the environs of H. Arctowski Station (South Shetlands, Antarctic). Acta Parasitol Pol 34:243–257

Zlotorzycka J, Modrzejewska M (1992) Contribution to the knowledge of lice Mallophaga from the Antarctic. Pol Polar Res 13:59–63