

1 **Emergence, spread, and impact of high pathogenicity avian** 2 **influenza H5 in wild birds and mammals of South America and** 3 **Antarctica, October 2022 to March 2024**

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28

29 **Abstract**

30 The currently circulating high pathogenicity avian influenza (HPAI) virus of the subtype H5
31 causes variable illness and death in wild and domestic birds and mammals, as well as in
32 humans. This virus evolved from the Goose/Guangdong lineage of HPAI H5 virus, which
33 emerged in commercial poultry in China in 1996, spilled over into wild birds, and spread
34 through Asia, Europe, Africa and North America by 2021, causing the deaths of hundreds of
35 millions of poultry and likely millions of wild birds. Our objective was to summarize the
36 spread and impact of HPAI H5 virus in wild birds and mammals in South America, evaluate
37 the risk of its spread and potential impact in Antarctic wildlife, and consider actions to
38 manage the current and future HPAI outbreaks in wildlife. We found in our review that the
39 virus arrived in South America in October 2022, followed by wide and rapid spread
40 throughout the continent, where it infected at least 83 wild bird species and 11 wild
41 mammal species, and is estimated to have killed at least 667,000 wild birds and 52,000 wild
42 mammals. HPAI H5 virus spread to the Antarctic region by October 2023 and to mainland
43 Antarctica by December 2023, associated with multiple mortality events in seabirds and

1 marine mammals. The high spatial density of colonies of various Antarctic species of birds
2 and mammals provides conditions for potentially devastating outbreaks with severe
3 conservation implications. Ecosystem-level impacts may follow and affected populations
4 may take decades to recover. Although little can be done to stop virus spread in wildlife, it is
5 important to continue targeted surveillance of wildlife populations for HPAI H5 virus
6 incursion, and assessment of the spread and impact of disease, both to provide information
7 for wildlife managers to adapt conservation plans, and to help policymakers mitigate and
8 prevent future HPAI outbreaks.

9

10 **Introduction**

11 The continued emergence of high pathogenicity avian influenza (HPAI) virus of the H5
12 subtype is a major hazard for wildlife health and conservation. In contrast to most infectious
13 disease agents, HPAI H5 virus has a broad host range among wild birds and mammals, is
14 highly infectious, and can cause high mortality. HPAI H5 virus therefore represents a novel
15 but poorly understood threat to a broad range of wild animal populations and their
16 ecosystems. This has been exemplified in South America, where HPAI H5 virus had not been
17 reported until 2022 and thus entered into wild bird and mammal populations that
18 presumably had never been exposed to that virus. It spread rapidly across the continent in
19 the following months, causing mass mortality events of unprecedented magnitude in many
20 wildlife species, in particular seabirds and marine mammals (Ariyama et al., 2023; Campagna
21 et al., 2023; Carrasco-Montalvo et al., 2023; Cruz et al., 2023; Leguia et al., 2023; Marandino
22 et al., 2023).

23 The current epidemic HPAI H5 virus is a descendant of the A/Goose/Guangdong/1/96
24 (Gs/GD) lineage. The term ‘high pathogenicity’ refers to the high morbidity and mortality
25 rates in infected chickens, not necessarily in other infected species. The term ‘H5’ refers to
26 the number of the hemagglutinin subtype to which this virus belongs; avian influenza viruses
27 are categorized in 16 subtypes based on the antigenic properties of their hemagglutinin
28 (Neumann, Treanor, & Kawaoka, 2021). While mortality from other HPAI viruses is mainly
29 restricted to poultry, the Gs/GD lineage is unusual in also causing mortality in wild birds and
30 mammals. Since its emergence, HPAI H5 has caused mortality in at least 356 species of wild
31 birds (Klaassen & Wille, 2023a), 49 species of wild mammals (European Food Safety
32 Authority et al., 2023) and hundreds of millions of poultry (Shi, Zeng, Cui, Yan, & Chen,
33 2023). It also has caused mortality in hundreds of people (Lai et al., 2016), with case fatality
34 rates varying between different clades, countries, time periods, and types of exposure. This
35 transmission of infection among a wide variety of species demonstrates the
36 interconnectedness of domestic animals, wildlife, humans, and their shared environment,
37 and highlights the need for a One Health approach to HPAI H5. The consensus definition of
38 the One Health approach was in 2021 formulated by the interdisciplinary One Health High-
39 Level Expert Panel and supported by the Food and Agriculture Organization, the World
40 Organization for Animal Health, the United Nations Environment Programme and the World
41 Health Organization, as “an integrated, unifying approach that aims to sustainably balance
42 and optimize the health of people, animals, and ecosystems. It recognizes that the health of
43 humans, domestic and wild animals, plants, and the wider environment (including

1 ecosystems) are closely linked and interdependent” (One Health High-Level Expert et al.,
2 2022; World Health Organization, 2021).

3 The Gs/GD lineage of HPAI H5 virus was first detected in commercially farmed geese in China
4 in 1996 and has circulated and evolved in poultry ever since (Xie et al., 2023). Multiple virus
5 variants within the Gs/GD lineage spread among the rapidly growing poultry populations in
6 Asia. In 2005, there was substantial spillover into migratory wild birds, and subsequent
7 spread to Europe and Africa. The virus caused numerous outbreaks in wild birds in Asia,
8 Europe and Africa in the following years, typically during autumn and winter with spread
9 primarily linked to migratory movements of wild birds. Additional resurgent events occurred
10 in 2014, 2016, and 2020, associated with the emergence of the 2.3.4.4 clade (Xie et al.,
11 2023). Since 2021, however, one clade of HPAI H5 virus (2.3.4.4b) has persisted year-round
12 in wild birds in Europe (Pohlmann et al., 2022). This clade of HPAI H5 virus (further referred
13 to as ‘HPAI H5 virus’ for the pathogen and ‘HPAI H5’ for the associated disease) spread
14 across both the Atlantic Ocean (in 2021) and the Pacific Ocean (in 2022) to North America
15 (Alkie et al., 2022; Caliendo et al., 2022), where it spread rapidly across the continent during
16 2022 and southwards, reaching Central and South America by October 2022 (European Food
17 Safety Authority et al., 2022), South Georgia (Islas Georgia del Sur) by October 2023
18 (Banyard et al., 2024) and the Antarctic Peninsula by February 2024 (Scientific Committee of
19 Antarctic Research, 2024).

20 Although national and international surveillance for HPAI H5 provides a relatively accurate
21 overview of the geographic spread of HPAI H5 and its impact on poultry populations, as well
22 as occurrence of human infections, surveillance and mortality estimates are limited in wild
23 birds and mammals (Klaassen & Wille, 2023b). Hence the picture of the spread and impact of
24 HPAI H5 in wildlife is fragmented across numerous reports and notifications, e.g., (Caliendo
25 et al., 2024; Camphuysen & Gear, 2022). We here define impact as a major effect on
26 affected wildlife species, including loss of individual lives, disruption of social structures such
27 as those between parents and offspring, and reduction of population numbers. Also, there is
28 little evidence by which routes HPAI H5 can spread through the Antarctic region as many
29 wildlife species in the region are unique to that continent and their movements through the
30 region are poorly understood (Bestley et al., 2020; Shirihai H, Jarrett B, Cox J, & GM., 2008).
31 Furthermore, the potential impact on Antarctic wildlife populations is unclear as exposure
32 risks and species susceptibility are poorly known. Therefore, the goals of this review were to:
33 1) synthesize data on spread of HPAI H5 virus and, as a measure of its impact, of associated
34 mortality in wildlife in South America and the Antarctic region; 2) evaluate potential
35 pathways for further introduction and virus spread through the Antarctic region; and 3)
36 review potential concerns for wildlife conservation of HPAI H5 emergence in South America
37 and Antarctica. By focusing on the impact of HPAI H5 on wildlife and ecosystems, which have
38 been relatively neglected compared to the impacts on poultry and people (Klaassen & Wille,
39 2023b; Kuiken et al., 2005), we support greater equity among the health of ecosystems, wild
40 and domestic animals, and humans, and so emphasize the One Health approach regarding
41 HPAI H5 (One Health High-Level Expert et al., 2022).

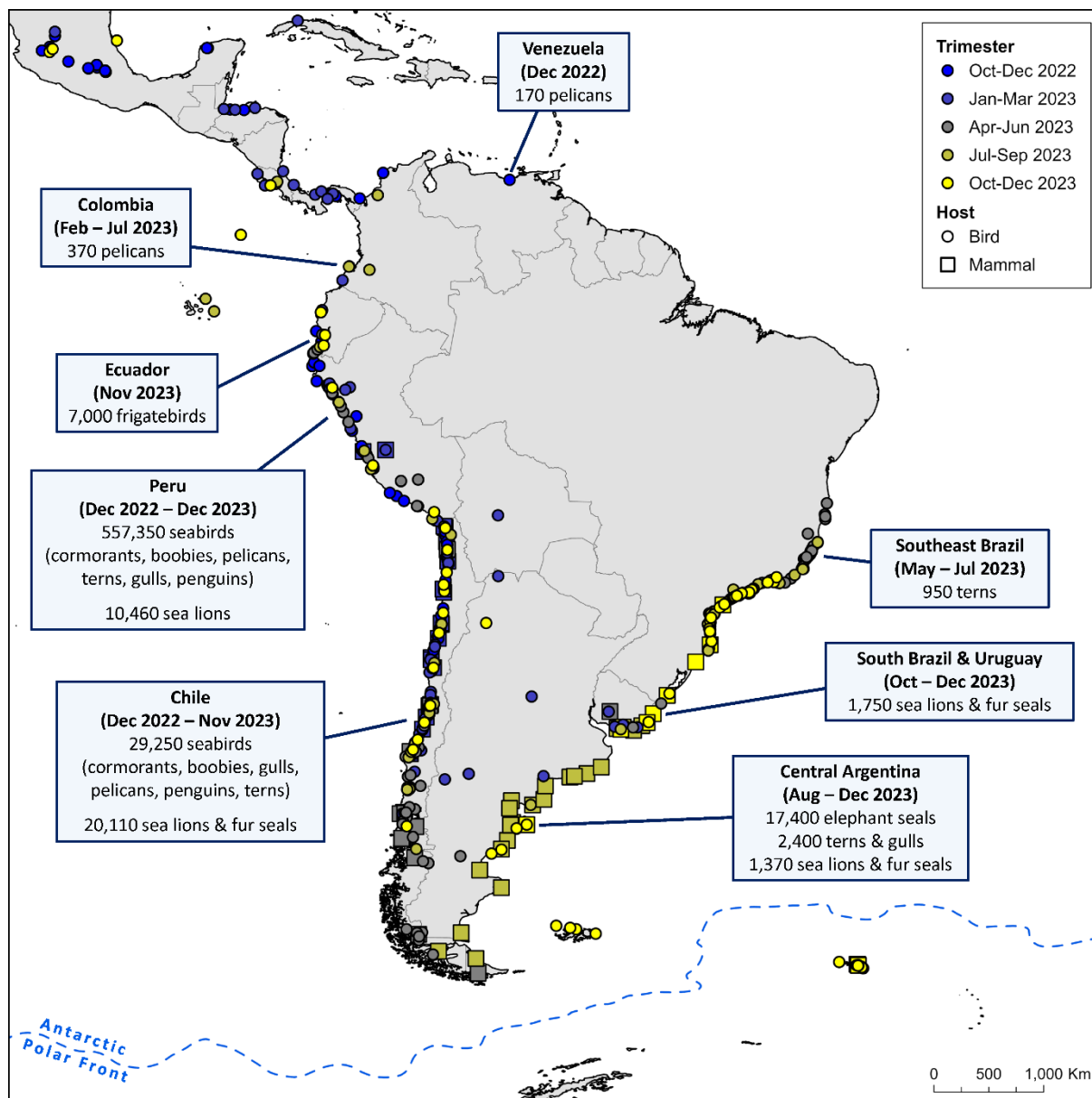
42 Data on HPAI H5 virus detection and reported wildlife deaths for Central America and South
43 America were obtained from reports to the World Organization for Animal Health (WOAH),
44 which are centrally archived on the website of the World Animal Health Information System
45 (WAHIS). These data were supplemented by data from websites of national government

1 websites of Argentina, Brazil, and Chile; newspaper articles (Brazil, Uruguay); and scientific
2 publications (Argentina, Brazil). Data for the Falkland Islands (Islas Malvinas) were obtained
3 from a national government website and a newspaper article. Data for South Georgia (Islas
4 Georgia del Sur) were obtained from a scientific publication and the website of the
5 Agreement on Conservation of Albatrosses and Petrels. Data for the Antarctic Peninsula
6 were obtained from the website of the Scientific Committee for Antarctic Research. Data on
7 numbers of individuals found dead per species and country were summed in Appendix S1.
8 HPAI H5 virus infection was confirmed in all reported species-country associations, with a
9 few specified exceptions.

10 **Spread of HPAI H5 through South America, October 2022 to December 2023**

11
12 In the year following its introduction into South America, HPAI H5 virus infected at least 83
13 wild bird species and 11 wild mammal species and was the probable cause of death of at
14 least 667,000 wild birds and 52,000 wild mammals (Figure 1, Appendix S1). (For ease of
15 reading, mortality counts above ten are rounded off to the nearest ten, hundred or
16 thousand, depending on the scale of mortality. Precise counts of dead animals are reported
17 in Appendix S1.) These data are derived from reports of HPAI H5 virus detections in wild
18 animals found ill or dead and mortality counts of wild animals during HPAI H5 outbreaks.
19 Numerical comparisons among countries may be unreliable since countries differ
20 considerably in their approach for surveillance, diagnostic methods and reporting of
21 suspected/confirmed HPAI cases. Also, the correlation between the distribution of wildlife
22 cases reported and human population density strongly suggests the potential for vast
23 underreporting in sparsely populated areas (Klaassen & Wille, 2023a). Therefore, these data
24 need to be interpreted with caution. For most species affected (e.g., pelicans, boobies,
25 cormorants, sea lions) there was robust evidence that the unusual mortality recorded in
26 South America during 2022-2023 was largely attributable to HPAI H5, with evidence
27 including the high frequency of HPAI H5 detection in carcasses, spatiotemporal patterns of
28 morbidity and mortality consistent with the epidemiology of an acute highly transmissible
29 disease and absence of other factors that could explain the mortality events. However, there
30 were a few species (e.g., shearwaters, ibises, parakeets) for which the evidence was less
31 robust, and it is plausible that other causes of mortality may have coincided with HPAI H5
32 outbreaks. Regarding the scale of mortality events, it is extremely unlikely that all sick or
33 dead animals were found and reported, especially in remote areas where observations and
34 surveillance effort were scarce. For example, collection rates of waterbird carcasses during
35 typical avian botulism outbreaks in the North American prairie are 10%–25% of total
36 mortality (Bollinger et al., 2011). Moreover, as the outbreaks extended over months and
37 then seasons, surveillance, detection and testing effort markedly decreased in the region,
38 with some countries in South America failing to report new wildlife cases since late 2023.
39 Therefore, the actual levels of wildlife mortality from HPAI H5 were undoubtedly much
40 higher than the reported counts.

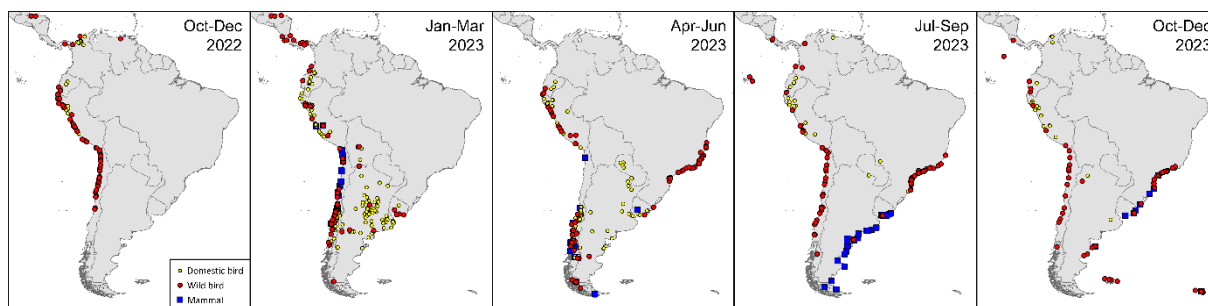
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1
2 **Figure 1:** Overall geographical locations of reported incidents of HPAI-H5-associated
3 mortality of wild birds and wild mammals in Central America, South America, and
4 neighbouring islands groups (Galápagos, Falkland/Malvinas, South Georgia/Georgia del Sur)
5 across time between October 2022 and December 2023. Selected major mortality events are
6 indicated in text boxes. For details of mortality reports, see Appendix S1.

7
8 The chronology of HPAI H5 virus detections and associated wildlife mortalities, combined
9 with genetic analyses (Banyard et al., 2024; Jimenez-Bluhm et al., 2023; Leguia et al., 2023;
10 Marandino et al., 2023; Pardo-Roa et al., 2023; Reischak et al., 2023; Rimondi et al., 2024)
11 suggests that HPAI H5 virus entered South America in October 2022, and that multiple
12 independent viral introduction events occurred (Cruz et al., 2023; Leguia et al., 2023). Not all
13 introduced viruses spread further through the continent. Following virus introduction, HPAI
14 H5 spread southwards along the west coast of South America (Peru and Chile) from
15 November 2022 to January 2023, and subsequently spread via two separate pathways: a)
16 eastward across the Andes to infect poultry and waterbirds on the La Plata Basin (Bolivia,

1 northern Argentina, Uruguay, and Paraguay) and inland areas of the Southern cone (central
 2 and southern Argentina) in February to April 2023 as well as to seabirds on the Atlantic coast
 3 (eastern Brazil) from June to October 2023; and b) southward along the southern Pacific
 4 coast (Chile) to infect seabirds and marine mammals (Castro-Sanguinetti et al., 2024),
 5 eventually reaching the southern tip of the continent and subsequently spreading
 6 northwards along the Atlantic coast (Argentina, Uruguay, and southern Brazil) from August
 7 to December 2023 (Figure 2). Below we describe events in South America from November
 8 2022 to December 2023.
 9



10

11 **Figure 2:** Progression per trimester of reported incidents of HPAI-H5-associated mortality of
 12 wild birds, wild mammals and domestic birds in Central America, South America, and
 13 neighbouring islands groups (Galápagos, Falkland/Malvinas, South Georgia/Georgia del Sur)
 14 from October 2022 to December 2023.

15

16

17 *Venezuela (November 2022)*

18

19 Among the first outbreaks of HPAI H5 in wildlife occurred in Venezuela in November 2022
 20 (WAHIS, 2022c) (Figure 1) affecting 200 brown pelicans (*Pelecanus occidentalis*) (WAHIS,
 21 2022d). This die-off in Venezuela is consistent with the relatively low mortality of wild birds
 22 reported in Central America in December 2022 and January 2023, specifically in Panama
 23 (Promed mail, 2022), Honduras (WAHIS, 2022b), Costa Rica (WAHIS, 2023f), and Guatemala
 24 (WAHIS, 2023h). Overall, numbers of wild birds reported dead in these countries were
 25 relatively low (hundreds) and mostly restricted to brown pelicans.

26

27 *Peru (December 2022 to December 2023)*

28

29 The largest HPAI-H5-associated mass mortality event occurred along the coast of Peru,
 30 affecting large numbers of seabirds and marine mammals that feed on abundant fish
 31 populations inhabiting the nutrient-rich Peruvian current upwelling ecosystem (Figure 1)
 32 (Peru Ministerio de Salud, 2023). About 558,000 seabirds of at least 14 species were found
 33 dead, mainly in the period December 2022 to June 2023 (Appendix S1, Figure 2). This
 34 number represents 84% of the total number of wild birds found dead in South America. The
 35 most frequently recorded species were cormorants (*Phalacrocoracidae* spp., n= 255,000),
 36 Peruvian boobies (*Sula variegata*, n=236,000), Peruvian pelicans (*Pelecanus thagus*,
 37 n=58,000), Inca terns (*Larosterna inca*, n=8,000) and gulls (*Larinae* spp., n=1,000). In
 38 addition, 11,000 South American sea lions (*Otaria byronia*) were found dead, mainly

1 between January to March 2023. A short-beaked common dolphin (*Delphinus delphis*) also
2 was found dead during that period.

3 4 *Chile (December 2022 to November 2023)*

5
6 There was HPAI-H5-associated mass mortality of aquatic birds—both sea and freshwater—
7 and marine mammals along the coast of Chile, part of the same Peruvian current upwelling
8 ecosystem as in Peru (Figure 1) (Chile Servicio Agrícola y Ganadero, 2023; Chile Servicio
9 Nacional de Pesca y Acuicultura, 2023). About 97,000 aquatic birds of at least 46 species
10 were found dead, mainly in the period December 2022 to June 2023 (Appendix S1, Figure 2).
11 The main species found dead were guanay cormorants (*Leucocarbo bougainvilliorum*,
12 n=30,000), sooty shearwaters (*Ardenna grisea*, n=24,000), Peruvian boobies (n=13,000), kelp
13 gulls (*Larus dominicanus*, n=6,000), Peruvian pelicans (n=6,000), Humboldt penguins
14 (*Spheniscus humboldti*, n=5,000), grey gulls (*Larus modestus*, n=4,000), neotropical
15 cormorants (*Nannopterum brasilianum*, n=1,000), black-necked swans (*Cygnus*
16 *melancoryphus*, n=1,000) and elegant terns (*Thalasseus elegans*, n=800). In addition to
17 aquatic birds, HPAI H5 was also detected in nine species of terrestrial birds, with 1,000
18 individuals found dead, mainly turkey vultures (*Cathartes aura*, n=600).

19
20 There also were 22,000 marine mammals of nine species found dead, mainly in the period
21 January to June 2023, starting a month later than reported seabird mortality (Chile Servicio
22 Agrícola y Ganadero, 2023; Chile Servicio Nacional de Pesca y Acuicultura, 2023). This
23 number represents 41% of the total number of wild mammals found dead in South America
24 in association with this HPAI H5 outbreak. The main species affected was the South
25 American sea lion (n=21,000), with more than double the mortality recorded in Peru. Other
26 marine mammal species affected included short-beaked common dolphins (n=60), marine
27 otters (*Lontra felina*) (n=50), Burmeister's porpoises (*Phocoena spinipinnis*, n=40), South
28 American fur seals (*Arctocephalus australis*, n=40), and Chilean dolphins (*Cephalorhynchus*
29 *eutropia*, n=20).

30 31 *Bolivia, Argentina, Paraguay, Uruguay and Brazil (January to June 2023)*

32
33 Starting in January 2023, a number of HPAI H5 outbreaks were recorded in poultry and wild
34 waterbirds along the Rio de la Plata basin across Bolivia (WAHIS, 2023b), Argentina (initially
35 at the north, then spreading southward to the Patagonian steppe) (Argentina Servicio
36 Nacional de Sanidad y Calidad Agroalimentaria, 2023; WAHIS, 2023a), Paraguay (WAHIS,
37 2023i), Uruguay (WAHIS, 2023j) and Southern Brazil (Brazil Ministério da Agricultura e
38 Pecuária, 2023a, 2023b; Reischak et al., 2023; WAHIS, 2023c). Most detections in wild
39 waterbirds were not accompanied by large-scale mortality, with the exception of isolated
40 clusters of mortality of black-necked swans (*Cygnus melancoryphus*, total n=300) in southern
41 Brazil, Uruguay and Argentina. By early May 2023 most of these outbreaks had resolved and
42 HPAI H5 detections dwindled. In mid-May 2023 a new wave of HPAI H5 detections emerged
43 in seabirds in Espirito Santo, eastern Brazil. Cayenne terns (*Thalasseus acuflavidus*
44 *eurygnathus*), royal terns (*Thalasseus maximus*) and South American terns (*Sterna*
45 *hirundinacea*) were most heavily affected, with over 1,000 birds found dead. While most of
46 the seabird mortality occurred in May and June 2023 and was concentrated in Espirito

1 Santo, HPAI H5 was detected sporadically in various species of seabirds found ashore (ill or
2 dead) throughout the southeastern and southern coast of Brazil over the following months,
3 suggesting continued HPAI H5 circulation in seabirds in the region.

4
5 *Colombia (February 2023)*

6
7 In February 2023, a brown pelican die-off in Colombia (Figure 1) occurred, affecting 400
8 individuals on Gorgona Island, near the country's Pacific coast (WAHIS, 2022a). This is the
9 only mass mortality event reported in Colombia thus far.

10
11 *Coastal Argentina (August to December 2023)*

12
13 There was HPAI-H5-associated mass mortality of marine mammals and later of seabirds
14 along the coast of Argentina (Figure 1) at the edge of the Patagonian Shelf, which extends
15 from 35 degrees Southern Latitude south to the tip of Tierra del Fuego, and from the coast
16 to approximately the 1000 m isobath (Falabella, Campagna, & Croxall, 2009; Raya Rey &
17 Huettmann, 2020). Between August and December, there were 19,000 marine mammals of
18 three species found dead along the Atlantic coast of Argentina (Appendix S1, Figure 2).
19 Although small numbers of South American sea lions were found dead in the south of
20 Argentina in August 2023 (Argentina Ministerio de Economía Secretaría de Agricultura
21 Ganadería y Pesca, 2023a, 2023b), mortality soon spread north along the country's entire
22 coast in August to December 2023, with more than 1,000 South American sea lions and
23 South American fur seals found dead at a few monitored sites (Argentina Ministerio de
24 Economía Secretaría de Agricultura Ganadería y Pesca, 2023a, 2023b). In October 2023,
25 there was a mass mortality of southern elephant seal pups (*Mirounga leonina*) attributed to
26 HPAI H5 in Peninsula Valdés, Chubut province. It was estimated that 97% of the pup
27 population died, comprising over 17,000 deaths, the most substantial mortality event
28 recorded for this species (Campagna et al., 2023).

29
30 Also, between October to November 2023, 3,000 seabirds of at least 10 species were found
31 dead along the shoreline. Terns were the most heavily affected, with 2,000 individuals found
32 dead across three species—South American terns, Cayenne terns and royal terns—at a few
33 monitored sites along the coast of Patagonia (Argentina Servicio Nacional de Sanidad y
34 Calidad Agroalimentaria, 2023). Because most tern breeding sites in this region were not
35 monitored during this period, the overall mortality was likely higher.

36
37 *Uruguay and southern Brazil (October to December 2023)*

38
39 Shortly after the mortality of pinnipeds in Argentina, an HPAI-H5-associated mass mortality
40 of more than 1,000 South American sea lions and South American fur seals (available reports
41 fail to distinguish between the two species) occurred along the coasts of Uruguay
42 (Anonymous, 2023a) and southern Brazil (Figure 1, Figure 2, Appendix S1) (Vara & Mano,
43 2023), in continuity with the mortality of pinnipeds recorded along the coast of Argentina.

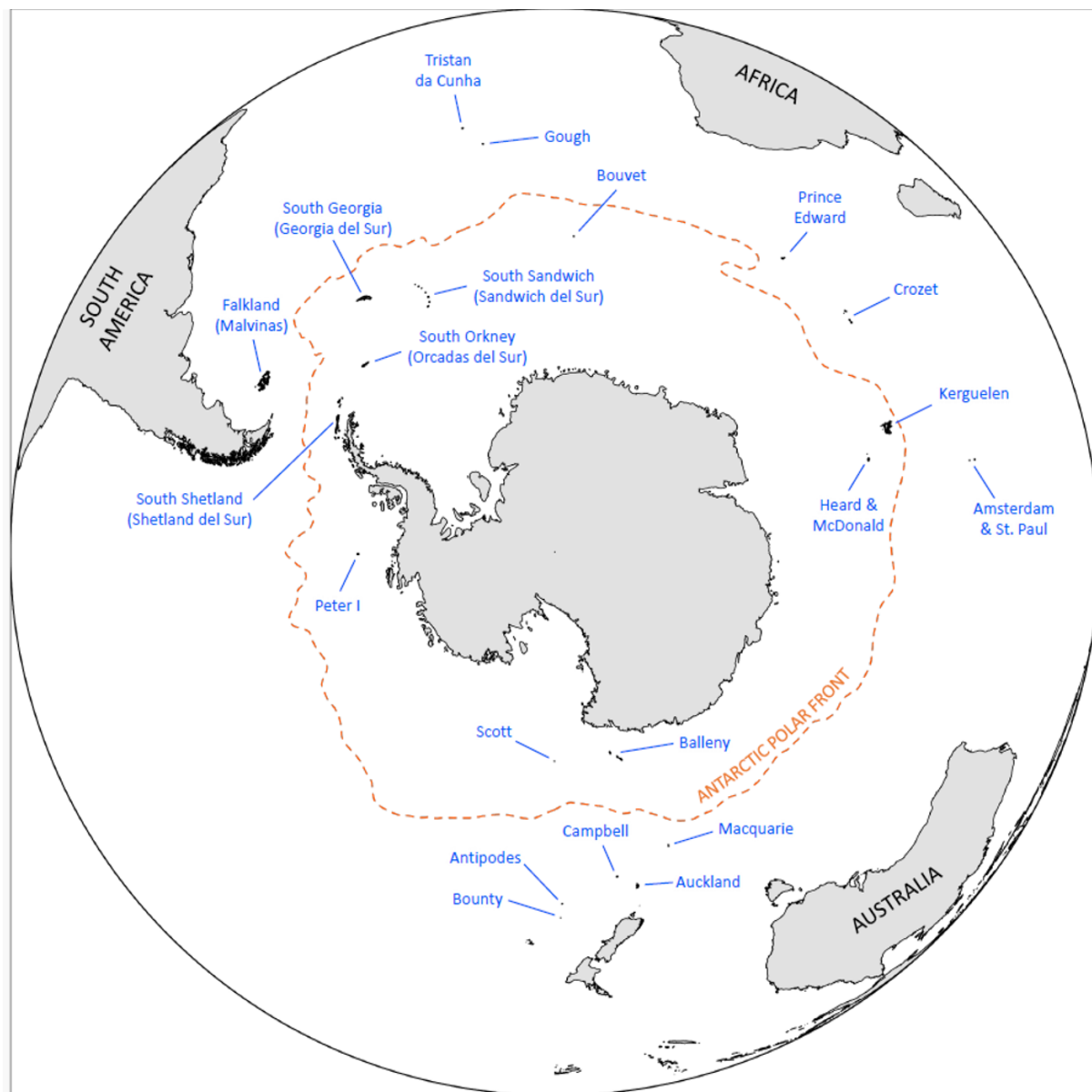
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45 *Ecuador (November 2023)*

46

1 Although HPAI H5 outbreaks were reported in Ecuadorian poultry since December 2022,
2 detections in wildlife were relatively scarce and not associated with large mortalities. In
3 November 2023, however, magnificent frigatebirds (*Fregata magnificens*, n=6,000) and great
4 frigatebirds (*Fregata minor*, n=1,000) were found dead in association with HPAI H5 virus
5 infection in areas of mangrove on the Ecuadorian coast (WAHIS, 2023g). These deaths had
6 been preceded in September 2023 by the detection of HPAI H5 in a small number of great
7 frigatebirds and red-footed boobies (*Sula sula*) on the Galápagos Islands (1,000 km west of
8 mainland Ecuador) (WAHIS, 2023g). Fortunately, these earlier detections at the Galápagos
9 were not associated with large wildlife mortality events.

11 **Risk of further HPAI H5 spread in the Antarctic region**

13 Following the rapid southbound movement of HPAI H5 through South America, its spread
14 through Antarctica is highly plausible. The geographical area of Antarctica is defined
15 differently according to different perspectives. The provisions of the Antarctic Treaty apply
16 to the area south of 60 degrees Southern Latitude (Antarctic Treaty, 2023)(Secretariat of the
17 Antarctic Treaty, 2023). However, biogeographically, the Antarctic region extends north of
18 this line and includes the waters and islands up to the Antarctic polar front, where colder
19 and nutrient-rich southern waters meet warmer northern waters (Figure 3). The Antarctic
20 polar front is also the boundary of the area of the Convention for the Conservation of
21 Antarctic Marine Living Resources (CCAMLR, 2023)(Commission for the Conservation of
22 Antarctic Marine Living Resources, 2023). In this paper, we will use the Antarctic polar front
23 as the boundary of the Antarctic region. This definition excludes the Falkland (Malvinas),
24 Gough, Prince Edward, Crozet, Amsterdam/St Paul, Macquarie, Auckland, Campbell, Bounty
25 and Antipodes islands, which we consider in this paper as part of the Subantarctic region
26 when discussing the spread and impacts of HPAI H5.



1
 2 **Figure 3:** Map of Antarctica, showing the approximate position of the Antarctic Polar Front
 3 (dashed blue line, drawn from Moore et al., 1999) and the location of Antarctic and
 4 Subantarctic island groups.

5
 6
 7 *Spread of HPAI H5 to the Falkland Islands and South Georgia, October to December 2023*

8
 9 The Falkland Islands (Islas Malvinas) are 1,000 km east of the mainland coast of Argentina
 10 and are part of the Patagonian Shelf. In October and November 2023, around the same time
 11 as seabird and marine mammal die-offs were reported along the coasts of Argentina and
 12 Uruguay (see above), HPAI H5 was detected in two southern fulmars (*Fulmarus glacialoides*)
 13 and one black-browed albatross (*Thalassarche melanophris*) found dead on the Falkland
 14 Islands (Falkland Islands Department of Agriculture, 2023). In December 2023, there was
 15 mortality of approximately 30 black-browed albatrosses attributed to HPAI H5 (Falkland
 16 Islands Department of Agriculture, 2023).

1
 2 South Georgia (Islas Georgia del Sur) is an archipelago within the Antarctic Polar Front and
 3 lies 1,000 km southeast of the Falkland (Malvinas) Islands. South Georgia is part of the Scotia
 4 Arc, a chain of islands between the southern tip of South America and the Antarctic
 5 Peninsula, which also include the South Sandwich Islands (Islas Sándwich del Sur), the South
 6 Orkney Islands (Islas Orcadas del Sur), and the South Shetland Islands (Islas Shetland del Sur).
 7 In October and November 2023, about 60 brown skuas (*Stercorarius antarcticus*), 20 kelp
 8 gulls, 1 Antarctic tern (*Sterna vittata*), and unspecified numbers of southern elephant seals
 9 and Antarctic fur seals (*Arctocephalus gazella*) were found dead in association with HPAI H5
 10 at multiple locations on South Georgia (Scientific Committee on Antarctic Research, 2023).
 11 Based on a limited number of publicly available virus sequences, genetic analysis showed the
 12 HPAI H5 virus from Bird Island to be most closely related to those from Uruguay, Peru and
 13 Chile collected between December 2022 and April 2023 (Banyard et al., 2024; Government
 14 of South Georgia and the South Sandwich Islands, 2023; Scientific Committee on Antarctic
 15 Research, 2023).

16
 17 *Significant recent events in Antarctic region, January to March 2024*

18
 19 HPAI-H5-associated deaths of more than 200 gentoo penguin (*Pygoscelis papua*) chicks and
 20 thousands black-browed albatross chicks on the Falkland Islands/Islas Malvinas were
 21 recorded in January 2024 (Mercopress, 2024), as well as in brown skuas and a variable hawk
 22 (*Geranoaetus polyosoma*) found dead in January and February 2024 (Scientific Committee of
 23 Antarctic Research, 2024). Mortality of more than 50 adult wandering albatrosses
 24 (*Diomedea exulans*) in South Georgia (Islas Georgia del Sur) in February 2024 was attributed
 25 to HPAI H5 (ACAP online news article, 2023; Falkland Islands Department of Agriculture,
 26 2023).

27
 28 Furthermore, HPAI H5 virus was detected in two skuas found dead in February 2024 on
 29 Primavera Cape, on the west coast of the Antarctic Peninsula, and in five skuas found dead
 30 on James Ross Island, off the north-east coast of the Antarctic Peninsula (Falkland Islands
 31 Department of Agriculture, 2023); it is unclear whether these were brown skuas or south
 32 polar skuas (*Stercorarius maccormicki*). These were the first detections of HPAI H5 on the
 33 continent of Antarctica (Scientific Committee of Antarctic Research, 2024).

34
 35 *Potential pathways for further introduction and spread of HPAI H5 in the Antarctic region*

36
 37 There are three main potential pathways through which additional incursion events into the
 38 Antarctic region could occur: (a) introduction to the Antarctic Peninsula by migratory species
 39 foraging on the Patagonian Shelf, (b) introduction to the Antarctic region by native Antarctic
 40 species overwintering throughout the austral temperate zone, and (c) introduction to the
 41 Antarctic region by trans-equatorial migratory species.

42
 43 (a) The Patagonian Shelf may be the most probable and frequent source for spread of
 44 HPAI H5 virus to the Antarctic region, with the Falkland (Malvinas) Islands and South
 45 Georgia (Islas Georgia del Sur) likely playing a role as stepping stones. Given that
 46 more than 60 species of resident and visiting seabirds forage on the Patagonian Shelf
 47 (Croxall & Wood, 2002; Falabella et al., 2009; Quintana, 2002; Raya Rey &

1 Huettmann, 2020; Salyuk et al., 2022; Zamora et al., 2023), there are myriad
2 scenarios by which seabirds may spread the virus further in the Antarctic region.
3 Preliminary evidence from virus genome sequence analysis suggests that seabirds
4 such as southern fulmars and brown skuas in which HPAI H5 was detected on the
5 Falkland (Malvinas) Islands and South Georgia may have been infected on the
6 Patagonian Shelf (Banyard et al., 2024). This is also supported by the numerous
7 detections of HPAI H5 virus in seabirds in Argentina and Uruguay in preceding
8 months (Argentina Servicio Nacional de Sanidad y Calidad Agroalimentaria, 2023;
9 Brazil Ministério da Agricultura e Pecuária, 2023b; WAHIS, 2023c). Seabirds could
10 transport HPAI H5 virus when migrating southwards to their breeding areas in the
11 Scotia Arc, the Antarctic Peninsula, and Antarctic and Subantarctic islands. In addition
12 to seabirds, marine mammals also should be considered as possible vectors of HPAI
13 H5 virus, assuming that some individuals may be infected without showing clinical
14 signs. Marine mammals may swim long distances in the period of infection, which in
15 seals has been shown to be about one week (Webster et al., 1981). For example,
16 southern elephant seals leave their breeding sites after breeding or moulting and
17 migrate south to Antarctica to feed on squid and fish at the edge of the sea-ice
18 (Lewis, Campagna, Marin, & Fernandez, 2006; McGovern et al., 2022; Rodriguez et
19 al., 2017). This implies that, from the Peninsula Valdés or South Georgia (Islas Georgia
20 del Sur), infected southern elephant seals could conceivably transport the virus to
21 the remainder of the Scotia Arc and to the Antarctic Peninsula. Further, marine
22 mammals that have succumbed to HPAI H5 may represent a source of infection for
23 avian species that feed on their carcasses.

- 24
25 (b) Species that are native to the Antarctic region could be exposed to HPAI H5 while
26 foraging at other areas in the austral temperate zone. For instance, Antarctic prions
27 (*Pachyptila desolata*), the most southerly breeding of all prion species, could play a
28 role in virus spread and amplification. HPAI H5 was detected in an individual found
29 dead on the southeast coast of Brazil in September 2023. This species breeds in large
30 numbers on islands of the Scotia Arc, Subantarctic islands in the Indian Ocean near
31 New Zealand, and probably on Scott Island near the Antarctic continent. They
32 congregate in large rafts at sea just before dusk and attend the colonies in huge
33 flocks just after dark, which would provide opportunities for HPAI H5 transmission.
34 After the breeding season, Antarctic prions disperse in a wide geographical range
35 between the Antarctic pack-ice and about 35°S. They are commonly found both on
36 the Patagonian Shelf as well as in the Humboldt Current off South America during the
37 austral winter (Navarro, Cardador, Brown, & Phillips, 2015; Quillfeldt, Masello,
38 Navarro, & Philips, 2013). Similarly, during the austral winter other seabirds such as
39 large numbers of various petrel species may also forage diffusely on open waters and
40 continental shelves of the austral temperate zone, and could be exposed to HPAI H5
41 through at-sea interactions with other subtropical and temperate species. The
42 susceptibility of petrel species is known from sporadic HPAI H5 detections in
43 southern giant petrels (*Macronectes giganteus*) found ashore in Chile, northern giant
44 petrels (*Macronectes halli*) and great-winged petrels (*Pterodroma macroptera*) in
45 Chile and South Africa and white-chinned petrels (*Procellaria aequinoctialis*) in Brazil
46 (Appendix S1).

47

1 (c) HPAI H5 could be introduced to the Antarctic region by trans-equatorial migratory
2 species such as Arctic terns (*Sterna paradisaea*), long-tailed jaegers (*Stercorarius*
3 *longicaudus*), or south polar skuas. For example, the south polar skua spends the
4 austral winter (boreal summer) in the North Pacific and North Atlantic and breeds in
5 relatively snow-free areas of Antarctica in the austral summer. Although this species
6 is usually reliant on fish, it can also survive exclusively on the predation/scavenging of
7 penguins in some areas (Kopp et al., 2011), which could provide opportunities for
8 transmission of HPAI H5 viruses acquired in the northern hemisphere.

9
10 Following introduction to Antarctica, there will likely be numerous opportunities for HPAI H5
11 virus spread within this region. The Scotia Arc and the Antarctic Peninsula are home to large
12 colonies of seabirds (especially penguins), Antarctic fur seals and southern elephant seals,
13 which are known or likely to be susceptible to HPAI H5 (Appendix S2). Low pathogenicity
14 avian influenza strains (subtypes H4N7, H5N5, H6N8, and H11N2) have been detected in
15 Adélie (*Pygoscelis adeliae*), gentoo and chinstrap penguins (*Pygoscelis antarcticus*), southern
16 giant petrels, snowy sheathbills (*Chionis albus*), and brown skuas, and phylogenetic analysis
17 indicates virus circulation in the Antarctic over several years (Barriga et al., 2016; de Seixas
18 et al., 2022; E. de Souza Petersen et al., 2017; Hurt et al., 2016; Hurt et al., 2014;
19 Ogrzewalska et al., 2022). This indicates that these species are suitable hosts for the
20 transmission and persistence of influenza viruses, and suggests that if introduced, HPAI H5
21 strains potentially could spread and cause significant impacts on these populations.

22
23 Further expansion to other parts of the continent is plausible given that many Antarctic birds
24 and pinnipeds probably are susceptible to infection and have overlapping ranges that form a
25 wide circumpolar band around Antarctica (BirdLife International, 2024; del Hoyo, Elliott,
26 Sargatal, & Collar, 1992-2008; IUCN, 2023) (Figure 4). Several seabirds such as albatrosses
27 are known to perform circumpolar movements in the Southern Ocean, and therefore could
28 support the longitudinal spread of HPAI H5 among Antarctic and Subantarctic islands (e.g.
29 visitors to breeding colonies) or transmission during interactions at sea (e.g. albatrosses and
30 petrels aggregating at foraging sites or near fishing vessels) (Agreement of the Conservation
31 of Albatrosses and Petrels, 2020). This would allow virus expansion along the Antarctic
32 continent and adjacent islands, where dense breeding colonies or other aggregations of
33 susceptible avian or mammalian hosts occur at variable distances of tens to hundreds of
34 kilometres from each other. The success of virus spread depends in part on the distance that
35 infected migrating hosts can travel while actively infected with respect to the distance
36 between colonies (Brown, Stallknecht, & Swayne, 2008; Ramis et al., 2014; Reperant et al.,
37 2011) and the success of virus transmission to hosts and amplification of the virus at
38 uninfected colonies, which likely increases with a higher number and density of susceptible
39 hosts at the colony.

40
41 Skuas and giant petrels, through their predatory and scavenging behaviour, visit numerous
42 sites along the southern tip of South America, Antarctic and Subantarctic islands, and the
43 Antarctic Peninsula. These habits and frequent incursions into breeding colonies of other
44 species, suggest these species could also play a significant role in the spread of HPAI H5
45 among sites in the Antarctic region. Brown skuas, southern fulmars and kelp gulls have
46 repeatedly been affected on the Falkland Islands (Islas Malvinas) and South Georgia (Islas
47 Georgia del Sur) and thus far have been among the first species affected in new locations.

1 Predatory and scavenging birds such as great skuas (*Catharacta skua*), gulls, corvids, raptors
2 and vultures have been involved in HPAI H5 outbreaks in the northern hemisphere (Animal
3 and Plant Health Inspection Service U.S. Department Of Agriculture, 2024; Camphuysen &
4 Gear, 2022; Giacinti et al., 2024; van den Brand et al., 2015; Wunschmann et al., 2024).

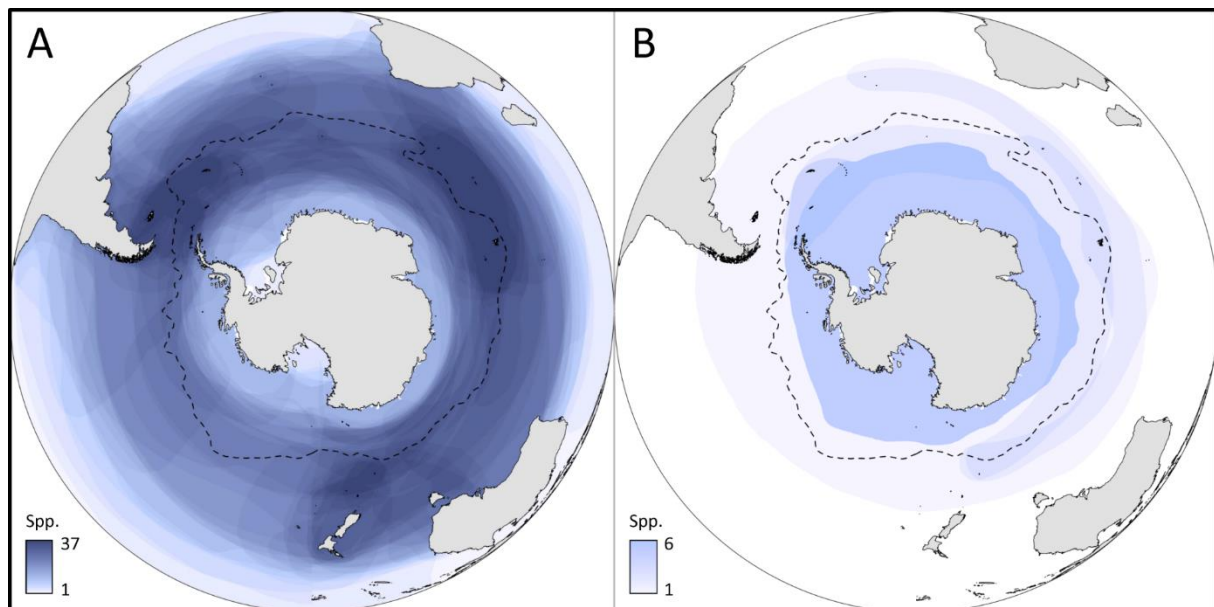
5 6 **Conservation implications**

7
8 The impacts of this HPAI H5 outbreak on wildlife in South America are enormous. Firstly, the
9 immense numbers of lives lost: more than 667,000 wild birds of 83 species and more than
10 52,000 wild mammals of 11 species reported dead between October 2022 and December
11 2023, with actual mortality likely many times larger. This has a direct conservation impact on
12 multiple wild bird and mammal species that are already threatened from other causes. This
13 includes species listed by the International Union for Conservation of Nature as being under
14 threat of extinction in the near future (IUCN, 2023). Based on the number of individuals
15 found dead, seabird species that suffered potential conservation impacts included Humboldt
16 penguin (vulnerable), and Peruvian pelican, red-legged cormorant (*Poikilocarbo gaimardi*),
17 sooty shearwater, elegant tern and Inca tern (all near-vulnerable). Mammal species that
18 suffered potential conservation impacts include marine otter and southern river otter
19 (*Lontra provocax*) (both endangered), and Chilean dolphin and Burmeister's porpoise (both
20 near-threatened) (Appendix S1).

21
22 If HPAI H5 virus spreads further across the Antarctic region, the negative impact on the
23 region's wild bird and mammalian populations could be immense, both because of their
24 likely susceptibility to mortality from this virus, and their occurrence in dense colonies
25 (Figure 4). Based on mortality events which have occurred elsewhere, bird species found on
26 Antarctica and the Subantarctic islands are likely highly susceptible to HPAI H5. Repeated
27 outbreaks in African penguins (*Spheniscus demersus*) in South Africa and Namibia (Molini et
28 al., 2020; Roberts et al., 2023), outbreaks in Humboldt penguins in Peru and Chile (see
29 above) and outbreaks in gentoo penguins on the Falkland Islands (Islas Malvinas) and South
30 Georgia (Islas Georgia del Sur) (see above) demonstrate that penguins are susceptible to
31 HPAI H5. The recent mortalities of black-browed albatrosses at the Falkland Islands (Islas
32 Malvinas) and of wandering albatrosses at South Georgia (Islas Georgia del Sur) confirm that
33 Procellariiformes are also highly susceptible, highlighting the potential conservation risk for
34 other endangered populations of these species. Beyond the avian taxa classically associated
35 with Antarctica, it is likely that the many species of endemic teals, cormorants, and
36 parakeets found on Subantarctic Islands are susceptible, too (Rijks et al., 2022; Roberts et al.,
37 2023; WAHIS, 2023d, 2023e). The impacts of HPAI H5 in this region will likely be exacerbated
38 by species endemism and colonial behaviour such that vast percentages of the world
39 population are concentrated into a few locations. For example, Steeple Jason Island in the
40 Falkland/Malvinas Islands hold 70% of the world population of black-browed albatross. The
41 occurrence of many of these species in dense colonies also likely facilitates rapid virus
42 transmission (Boulinier, 2023). Antarctic and Subantarctic birds already face a myriad of
43 challenges, including declining prey abundance, fisheries bycatch and climate change. We
44 therefore consider HPAI H5 a major conservation threat to all endemic Antarctic and
45 Subantarctic bird species.

46

1 Likewise, pinniped populations present in the Subantarctic and Antarctic regions also are
 2 probably susceptible to infection and mortality from HPAI H5. All six Antarctic pinniped
 3 species belong to the families Otariidae or Phocidae (Appendix S2), both of which have been
 4 extensively affected by HPAI H5 in South America (Campagna et al., 2024; Leguia et al.,
 5 2023). Given the substantial HPAI-H5-associated mass mortalities of South American fur
 6 seals in southern Brazil and Uruguay, it is probable that the fur seals of the Antarctic region
 7 would also be highly susceptible such that catastrophic impacts to the species' most
 8 significant populations may ensue. For example, 95% of the global population of the
 9 Antarctic fur seal is concentrated at South Georgia (Islas Georgia del Sur), (IUCN, 2023) and
 10 there has been HPAI-H5-attributed mortality since October 2023. Similarly, approximately
 11 50% of the global population of the southern elephant seal is concentrated at South Georgia
 12 (Islas Georgia del Sur) (Boyd et al., 1996), and deaths associated with HPAI H5 have been
 13 reported there since October 2023 (Banyard et al., 2024; Government of South Georgia and
 14 the South Sandwich Islands, 2023). The most severe HPAI H5 impact in this species so far has
 15 been at Peninsula Valdés, Argentina, where 97% of pups died in October and November
 16 2023 (Campagna et al., 2023).
 17



18
 19 **Figure 4:** Marine distribution of seabird diversity (A), and pinniped diversity (B). These maps
 20 show the number of avian and pinniped species occurring per location, as a measure of the
 21 potential for HPAI H5 virus to spread. Avian and pinniped diversity are drawn using the same
 22 colour gradient and were derived from publicly available species distribution maps (BirdLife
 23 International and Handbook of the Birds of the World, 2019; IUCN, 2023).

24
 25 Five of 17 Antarctic cetacean species belong to the families Delphinidae or Phocoenidae
 26 (Appendix S2), in which HPAI-H5-associated mortality has thus far been detected in Peru and
 27 Chile (Chile Servicio Nacional de Pesca y Acuicultura, 2023; Leguia et al., 2023) as well as in
 28 the northern hemisphere (Murawski et al., 2023; Thorsson et al., 2023). The mechanisms of
 29 transmission of HPAI H5 to cetaceans remain unclear and no mass mortalities of cetaceans
 30 have been attributed to the virus. However, it is plausible that at-sea mortalities have gone

1 undetected. Therefore, it would be prudent to consider cetaceans as potentially susceptible
2 to HPAI H5 in Antarctica.

3
4 Overall, HPAI H5 is a major conservation concern, not just in the short term, but also in long-
5 term impacts on populations. For example, populations of long-lived species of birds and
6 mammals could take decades to recover, particularly if HPAI outbreaks recur in consecutive
7 years and the disease kills adult females. Moreover, species currently listed as Least Concern
8 (IUCN) could become threatened, with important consequences for conservation priorities.

9
10 In addition to conservation challenges for directly affected wildlife species, HPAI H5 may
11 have large ecosystem-level impacts. For example, following Antarctic whaling, the mass
12 removal of animals had substantial ecosystem-level impacts, including species extinction,
13 breakdown of predatory-prey interactions, modification of nutrient cycling, breakdown in
14 carbon sequestration and thus increased CO₂ emissions, negative impacts on global marine
15 productivity and shifts in species compositions (Herr et al., 2022; Roman et al., 2014). If HPAI
16 H5 were to cause mass mortality events in Antarctica to the scale of those reported in South
17 America, this mass “removal” of animals from the landscape could have similar, profound,
18 impacts on Antarctic coastal and marine ecosystems.

19

20 **Managing the ongoing HPAI H5 outbreak**

21

22 Now that HPAI H5 virus has spilled over into wildlife and is no longer dependent on poultry
23 for its continued transmission, there is little that can be done to stop the spread of this virus
24 among free-living populations. Nevertheless, there are a few actions that may help to lower
25 the impact of the ongoing HPAI H5 outbreak for wildlife:

- 26 1. Surveying wildlife populations for the presence of HPAI H5 virus based on evidence of
27 unusual morbidity and mortality and virological and serological analyses, including timely
28 sharing of disease diagnosis and of viral genome sequences. This will enable prompt
29 detection of new virus introductions and monitoring of virus evolution through
30 phylogenetic analyses, which are relevant for both animal and human health.
- 31 2. Recording mortality events in wildlife comprehensively and collecting information and
32 samples to substantiate the cause or causes of mortality. Well-documented descriptions
33 of HPAI H5 outbreaks in wildlife are required to evaluate the impact of this disease on
34 wildlife populations. Due to its relative remoteness, avian influenza surveillance and
35 investigation of unusual wildlife mortality events require careful advance planning and
36 coordination among the scientists from different countries interested in working on
37 avian influenza in Antarctica. This is done through the Antarctic Wildlife Health Network
38 of the Scientific Committee on Antarctic Research (Scientific Committee on Antarctic
39 Research, 2023).
- 40 3. Removing infected carcasses as early as possible and repeatedly at wild bird breeding
41 sites that are intensively monitored and managed. While there are studies that suggest
42 that carcass removal is effective to reduce contamination and transmission to other
43 animals (Knief et al., 2024; Reperant, Caliendo, & Kuiken, 2021; Rijks et al., 2022;
44 Yamamoto, Nakamura, & Mase, 2017), efficacy in different scenarios remains uncertain.
45 In Antarctica there are additional challenges associated with carcass removal due to rules
46 preventing carcass burial and the lack of incinerators (Dewar et al., 2023). Also, the

- 1 potential benefits of removing carcasses need to be weighed up against the potential
2 adverse effects of repeated disturbance of breeding colonies.
- 3 4. Reducing non-essential human activities (e.g. tourism, extraction/exploitation of natural
4 resources) at affected sites, to prevent unintentionally spreading the virus and to
5 minimize the risks of human exposure. Rules for tourism are of particular relevance to
6 Antarctica, where there were 122,072 tourists in the 2023-2024 austral season
7 (International Association of Antarctica Tour Operators, 2024). These measures may also
8 be particularly important at breeding sites of affected birds and mammal species, in
9 order to reduce disturbance and enhance post-outbreak population recovery.
- 10 5. Essential human activities (e.g. research, implementation of conservation measures) at
11 affected sites should involve appropriate biosafety measures, such as disinfection of
12 footwear and the use of personal protective equipment. Some measures need to be
13 adapted to the unique circumstances in the sub-Antarctic and Antarctica (Dewar et al.,
14 2023). This aims both to reduce the risk of human-caused spread of virus to other
15 wildlife populations, and to protect people exposed to HPAI H5 virus from infected
16 animals.

17

18 Under no circumstance should disease control measures include consideration of killing of
19 wild birds or mammals, spraying toxic products or negatively affecting wetlands and other
20 habitats, nor deterring animals from access to their habitat. This is based on advice of the
21 Food and Agriculture Organization (FAO) and the World Organisation for Animal Health
22 (WOAH), and international obligations under the Convention on Migratory Species (CMS),
23 the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA) and
24 the Ramsar Convention on Wetlands (CMS & FAO, 2023)(Birds, 2023).

25

26 **Concluding remarks**

27

28 A consequence of the Anthropocene with human beings as the dominating factor on Earth is
29 an increase in the rate of emerging infectious disease events. These events include diseases
30 spilling over from farmed or traded animals into free-ranging wildlife populations, such as
31 mycoplasmosis from poultry to North American songbirds (Dhondt et al., 2005), African
32 swine fever from domestic pigs to Eurasian wild boar and Asian wild pigs (Luskin et al.,
33 2020), and HPAI H5 from poultry to multiple species of wild birds and mammals world-wide
34 (Wille & Barr, 2022). This is a paradigm shift where wildlife is not just a source but also a
35 victim of emerging infectious diseases (Kuiken & Cromie, 2022).

36

37 A parallel paradigm shift is needed in infectious disease prevention and control to prevent
38 escalation of emerging infectious disease events in wildlife, livestock and humans from
39 happening in the future, as well as to minimize their impacts when they do occur. To this
40 end, we advocate a One Health approach, which aims to optimize health not only of people
41 and livestock, but also of wildlife and ecosystems. Such a One-Health-based paradigm shift
42 includes integrating previously siloed government departments of agriculture, public health
43 and environment; building a One-Health workforce capable of handling these complex
44 wicked problems; and greatly increasing financial support for research, surveillance and
45 management of emerging infectious disease events in wildlife and ecosystems, to similar
46 levels as for livestock and people.

47

1 The current HPAI H5 outbreak, which stems from a virus that emerged in a rapidly expanding
2 poultry sector in eastern Asia, has led to catastrophic impacts on seabird and pinniped
3 populations in South America. This highlights that ecosystems are globally connected, that
4 viruses do not recognize political or species barriers, and that once such an adaptable virus
5 spills over into wildlife, it is out of our control. To prevent future HPAI outbreaks in wildlife,
6 reduce risk for humans and protect food security, we need to recognise the links between
7 livestock production, wildlife populations and ecosystem health in disease prevention,
8 preparedness and response. Moreover, we need to be proactive in addressing the drivers of
9 disease emergence, with a renewed focus on biodiversity conservation.
10

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26 to support and coordinate global efforts to prevent, detect and control important influenzas
27 in animals.

28

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28

29 **APPENDICES:**

Appendix S1: Number of birds and mammals reported dead from 1 November 2022 to 10th of December 2023 by countries in South America.

Asterisks indicate species-country associations where HPAI H5 virus infection was not confirmed by at least one case. Numerical comparisons among countries may be unreliable since countries differ considerably in their approach for surveillance, diagnostic methods and reporting of suspected/confirmed HPAI cases.

Family / Common name /Species name		IUCN Red List assessment	Estimated global population size	Number of individuals reported dead per country ⁴									
				Bolivia	Peru	Chile	Argentina	Ecuador	Brazil	Uruguay	Colombia	Venezuel	
Birds													
Accipitridae													
Great black hawk	<i>Buteogallus urubitinga</i>	Least concern	500,000-4,999,999 ³							1			
Black-chested buzzard-eagle	<i>Geranoaetus melanoleucus</i>	Least concern	unknown ^{1,3}		13	1							
Harris's hawk	<i>Parabuteo unicinctus</i>	Least concern	unknown ^{1,3}			2							
Anatidae													
White-cheeked pintail	<i>Anas bahamensis</i>	Least concern	177,000 – 1,080,000 ²		1		3						

Family / Common name /Species name		IUCN Red List assessment	Estimated global population size	Number of individuals reported dead per country ⁴										
				Bolivia	Peru	Chile	Argentina	Ecuador	Brazil	Uruguay	Colombia	Venezuel		
Yellow-billed teal	<i>Anas flavirostris</i>	Least concern	1,043,000 – 1,133,000 ²			1								
Yellow-billed pintail	<i>Anas georgica</i>	Least concern	100,000 – 1,000,000 ²			1								
Black-necked swan	<i>Cygnus melancoryphus</i>	Least concern	25,000 – 100,000 ²			107	21		1	142				
Black-bellied whistling-duck	<i>Dendrocygna autumnalis</i>	Least concern	200,000-2,000,000 ²								1			
White-faced whistling-duck	<i>Dendrocygna viduata</i>	Least concern	2,100,000 – 2,500,000 ²								1			
Chiloé wigeon	<i>Mareca sibilatrix</i>	Least concern	100,000 – 1,000,000 ²			1								
Silver teal	<i>Spatula versicolor</i>	Least concern	50,000 – 200,000 ²				1							
Andean goose	<i>Chloephaga melanoptera</i>	Least concern	25,000 – 100,000 ²		102		2							

Family / Common name /Species name		IUCN Red List assessment	Estimated global population size	Number of individuals reported dead per country ⁴									
				Bolivia	Peru	Chile	Argentina	Ecuador	Brazil	Uruguay	Colombia	Venezuel	
Hirundinidae													
Blue-and-white swallow	<i>Pygochelidon cyanoleuca</i>	Least concern	5,000,000-50,000,000 ³	4									
Laridae													
Inca tern	<i>Larosterna inca</i>	Near threatened	150,000 ²		7987	239							
Belcher's gull	<i>Larus belcheri</i>	Least concern	1 – 10,000 ²			293							
Grey-headed gull	<i>Larus cirrocephalus</i>	Least concern	250,000 – 540,000 ²					1	2				
Kelp gull	<i>Larus dominicanus</i>	Least concern	3,287,000 – 4,290,000 ²		1063	4594	1						
Brown-hooded gull	<i>Larus maculipennis</i>	Least concern	100,000 – 1,000,000 ²			48			1				
Grey gull	<i>Larus modestus</i>	Least concern	25,000 ²			1016							

Family / Common name /Species name		IUCN Red List assessment	Estimated global population size	Number of individuals reported dead per country ⁴										
				Bolivia	Peru	Chile	Argentina	Ecuador	Brazil	Uruguay	Colombia	Venezuel		
House sparrow	<i>Passer domesticus</i>	Least concern	896,000,000-1,310,000,000 ³			1								
Pelecanidae														
Brown pelican	<i>Pelecanus occidentalis</i>	Least concern	345,000 – 400,000 ²								30	17		
Peruvian pelican	<i>Pelecanus thagus</i>	Near threatened	100,000 - 1,000,000 ²		57447	4509								
Phalacrocoracidae														
Imperial shag	<i>Leucocarbo atriceps</i>	Least concern	333,000 - 1.360.000 ²			7								
Guanay cormorant	<i>Leucocarbo bougainvilliorum</i>	Near threatened	2,500,00 – 5,000,000 ²			6380								
Neotropical cormorant	<i>Nannopterum brasilianus</i>	Least concern	2,160,000 – 3,150,000 ²		254793	726			1					

Family / Common name /Species name		IUCN Red List assessment	Estimated global population size	Number of individuals reported dead per country ⁴									
				Bolivia	Peru	Chile	Argentina	Ecuador	Brazil	Uruguay	Colombia	Venezuel	
Southern giant petrel	<i>Macronectes giganteus</i>	Least concern	95,600-108,000 ¹			7							
Antarctic prion	<i>Pachyptila desolata</i>	Least concern	50,000,000 ¹						1				
Peruvian diving petrel	<i>Pelecanoides garnotii</i>	Near threatened	100,000 ¹			25							
White-chinned petrel	<i>Procellaria aequinoctialis</i>	Vulnerable	3,000,000 ¹						1				
Manx shearwater	<i>Puffinus puffinus</i>	Least concern	680,000-790,000 ¹						3				
Psittacidae													
Slender-billed parakeet	<i>Enicognathus leptorhynchus</i>	Least concern	Unknown ^{1,3}			14							
Rallidae													
Red-gartered coot	<i>Fulica armillata</i>	Least concern	1,000,000 ²			2							

Family / Common name /Species name		IUCN Red List assessment	Estimated global population size	Number of individuals reported dead per country ⁴									
				Bolivia	Peru	Chile	Argentina	Ecuador	Brazil	Uruguay	Colombia	Venezuel	
Brown skua	<i>Catharacta antarctica</i>	Least concern	26,000-28,000 ¹										
Chilean skua	<i>Catharacta chilensis</i>	Least concern	2,500-9,999 ¹		25	6							
Strigidae													
Tropical screech-owl	<i>Megascops choliba</i>	Least concern	500,000-4,999,999 ¹						1				
Sulidae													
Brown booby	<i>Sula leucogaster</i>	Least concern	200,000 ¹						3				
Blue-footed booby	<i>Sula nebouxii</i>	Least concern	90,000 ¹		4			3					
Red-footed booby	<i>Sula sula</i>	Least concern	1,400,000 ¹					6					

Family / Common name /Species name		IUCN Red List assessment	Estimated global population size	Number of individuals reported dead per country ⁴										
				Bolivia	Peru	Chile	Argentina	Ecuador	Brazil	Uruguay	Colombia	Venezuel		
Marine otter	<i>Lontra felina</i>	Endangered	unknown			43								
Southern river otter	<i>Lontra provocax</i>	Endangered	unknown			1								
Otariidae														
South American fur seal	<i>Arctocephalus australis</i>	Least concern	109,500 ³			27*	13							
South American sea lion	<i>Otaria byronia</i>	Least concern	222,500 ³		10457	20070	1367		552	800				
Phocidae														
Southern elephant seal	<i>Mirounga leonina</i>	Least concern	325,000 ³			16*	17400							
Procyonidae														
South American coati	<i>Nasua nasua</i>	Least concern	unknown							16				

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⁵FMI: Falklands (Malvinas) Islands

Appendix S2: List of species of Antarctic and Subantarctic birds and mammals with IUCN Red List assessment and estimated populations

Family	Common name	Species	IUCN Red list assessment	Estimated global population size
Birds				
Anatidae	Southern pintail	<i>Anas eatoni</i>	Vulnerable	47,000-62,000 ²
	Yellow-billed pintail	<i>Anas georgica</i>	Least concern	1,800–13,000 ²
Chionidae	Snowy sheathbill	<i>Chionis albus</i>	Least concern	unknown ^{1,3}
	Black-faced sheathbill	<i>Chionis minor</i>	Least concern	8,700-13,000 ¹
Diomedeidae	Wandering albatross	<i>Diomedea exulans</i>	Vulnerable	20,100 ¹
	Sooty albatross	<i>Phoebetria fusca</i>	Endangered	21,234-28,656 ¹
	Light-mantled albatross	<i>Phoebetria palpebrata</i>	Near threatened	58,000 ¹

Family	Common name	Species	IUCN Red list assessment	Estimated global population size
	Indian yellow-nosed albatross	<i>Thalassarche carteri</i>	Endangered	82,000 ¹
Diomedeidae	Grey-headed albatross	<i>Thalassarche chrysostoma</i>	Endangered	250,000
	Black-browed albatross	<i>Thalassarche melanophris</i>	Least concern	1,400,000 ¹
Laridae	Kelp gull	<i>Larus dominicanus</i>	Least concern	3,117,000–3,222,000 ²
	Kerguelen tern	<i>Sterna virgata</i>	Near threatened	3,500-6,500 ²
	Antarctic tern	<i>Sterna vittata</i>	Least concern	133,000-144,000 ²
Motacillidae	South Georgia pipit	<i>Anthus antarcticus</i>	Least concern	6,000-8,000 ¹
Oceanitidae	Black-bellied storm petrel	<i>Fregetta tropica</i>	Least concern	500,000 ¹
	Grey-backed storm petrel	<i>Garrodia nereis</i>	Least concern	200,000 ¹

Family	Common name	Species	IUCN Red list assessment	Estimated global population size
	Wilson's storm petrel	<i>Oceanites oceanicus</i>	Least concern	8,000,000-20,000,000 ¹
Phalacrocoracidae	Imperial shag	<i>Leucocarbo atriceps</i>	Least concern	333,000 - 1.360.000 ²
	Kerguelen shag	<i>Leucocarbo verrucosus</i>	Least concern	unknown ^{1,3}
Procellariidae	Kerguelen petrel	<i>Aphrodroma brevirostris</i>	Least concern	1,000,000 ¹
	Cape petrel	<i>Daption capense</i>	Least concern	2,000,000 ¹
	Southern fulmar	<i>Fulmarus glacialoides</i>	Least concern	4,000,000 ¹
	Blue petrel	<i>Halobaena caerulea</i>	Least concern	3,000,000 ¹
Procellariidae	Southern giant petrel	<i>Macronectes giganteus</i>	Least concern	95,600-108,000 ¹
	Northern giant petrel	<i>Macronectes halli</i>	Least concern	23,600 ¹

Family	Common name	Species	IUCN Red list assessment	Estimated global population size
	Slender-billed prion	<i>Pachyptila belcheri</i>	Least concern	7,000,000 ¹
	Fulmar prion	<i>Pachyptila crassirostris</i>	Least concern	150,000-300,000 ¹
	Antarctic prion	<i>Pachyptila desolata</i>	Least concern	50,000,000 ¹
	Salvin's prion	<i>Pachyptila salvini</i>	Least concern	12,000,000 ¹
	Fairy prion	<i>Pachyptila turtur</i>	Least concern	5,000,000 ¹
	Snow petrel	<i>Pagodroma nivea</i>	Least concern	4,000,000 ¹
	South Georgia diving petrel	<i>Pelecanoides georgicus</i>	Least concern	15,000,000 ¹
	Common diving petrel	<i>Pelecanoides urinatrix</i>	Least concern	16,000,000 ¹
	White-chinned petrel	<i>Procellaria aequinoctialis</i>	Vulnerable	3,000,000 ¹

Family	Common name	Species	IUCN Red list assessment	Estimated global population size
	Grey petrel	<i>Procellaria cinerea</i>	Near threatened	151,500 ¹
	White-headed petrel	<i>Pterodroma lessonii</i>	Least concern	600,000 ¹
	Great-winged petrel	<i>Pterodroma macroptera</i>	Least concern	1,500,000 ¹
	Soft-plumaged petrel	<i>Pterodroma mollis</i>	Least concern	5,000,000 ¹
	Antarctic petrel	<i>Thalassoica antarctica</i>	Least concern	10,000,000-20,000,000 ¹
Spheniscidae	Emperor penguin	<i>Aptenodytes forsteri</i>	Near threatened	>550,000 ¹
	King penguin	<i>Aptenodytes patagonicus</i>	Least concern	>2,200,000 ¹
	Southern rockhopper penguin	<i>Eudyptes chrysocome</i>	Vulnerable	2,500,000 ¹
	Macaroni penguin	<i>Eudyptes chrysolophus</i>	Vulnerable	>12,600,000 ¹

Family	Common name	Species	IUCN Red list assessment	Estimated global population size
	Adelie penguin	<i>Pygoscelis adeliae</i>	Least concern	14,000,000-16,000,000 ¹
	Chinstrap penguin	<i>Pygoscelis antarcticus</i>	Least concern	8,000,000 ¹
	Gentoo penguin	<i>Pygoscelis papua</i>	Least concern	774,000 ¹
Stercorariidae	Brown skua	<i>Catharacta antarctica</i>	Least concern	26,000-28,000 ¹
	South polar skua	<i>Catharacta maccormicki</i>	Least concern	6,000-15,000 ¹
Mammals				
Balaenidae	Southern right whale	<i>Eubalaena australis</i>	Least concern	unknown
Balaenopteridae	Sei whale	<i>Balaenoptera borealis</i>	Endangered	50,000 ³

Family	Common name	Species	IUCN Red list assessment	Estimated global population size
	Antarctic blue whale	<i>Balaenoptera musculus intermedia</i>	Critically endangered	3,000 ³
	Common minke whale	<i>Balaenoptera acutorostrata</i>	Least concern	200,000 ³
	Fin whale	<i>Balaenoptera physalus</i>	Vulnerable	100,000 ³
	Humpback whale	<i>Megaptera novaeangliae</i>	Least concern	84,000 ³
	Antarctic minke whale	<i>Balaenoptera bonaerensis</i>	Near threatened	unknown
Delphinidae	Commerson's dolphin	<i>Cephalorhynchus commersonii</i>	Least concern	unknown
	Long-finned pilot whale	<i>Globicephala melas</i>	Least concern	unknown
	Hourglass dolphin	<i>Lagenorhynchus cruciger</i>	Least concern	unknown
	Southern right whale dolphin	<i>Lissodelphis peronii</i>	Least concern	unknown

Family	Common name	Species	IUCN Red list assessment	Estimated global population size
	Killer whale	<i>Orcinus orca</i>	Data deficient	unknown
Neobalaenidae	Pygmy right whale	<i>Caperea marginata</i>	Least concern	unknown
Otariidae	Antarctic fur seal	<i>Arctocephalus gazella</i>	Least concern	700,000-1,000,000 ³
	Subantarctic fur seal	<i>Arctocephalus tropicalis</i>	Least concern	200,000 ³
	South American sea lion	<i>Otaria byronia</i>	Least concern	222,500 ³
Phocidae	Leopard seal	<i>Hydrurga leptonyx</i>	Least concern	18,000 ³
	Weddell seal	<i>Leptonychotes weddellii</i>	Least concern	300,000 ³
	Crabeater seal	<i>Lobodon carcinophagus</i>	Least concern	4,000,000 ³
	Southern elephant seal	<i>Mirounga leonina</i>	Least concern	325,000 ³
	Ross seal	<i>Ommatophoca rossii</i>	Least concern	40,000 ³

Family	Common name	Species	IUCN Red list assessment	Estimated global population size
Phocoenidae	Spectacled porpoise	<i>Phocoena dioptrica</i>	Least concern	unknown
Physeteridae	Sperm whale	<i>Physeter macrocephalus</i>	Vulnerable	unknown
Ziphiidae	Gray's beaked whale	<i>Mesoplodon grayi</i>	Least concern	unknown
	Southern bottlenose whale	<i>Hyperoodon planifrons</i>	Least concern	unknown
	Strap-toothed whale	<i>Mesoplodon layardii</i>	Least concern	unknown
	Arnoux's beaked whale	<i>Berardius arnuxii</i>	Least concern	unknown

¹Population estimate (number of mature individuals) based on data from BirdLife International's "IUCN Red List for birds". Downloaded from <https://datazone.birdlife.org> in March 2024.

²Population estimate (total population) based on data from Wetlands International's "Waterbird Populations Portal". Retrieved from wpp.wetlands.org in March 2024.

³Population estimate (number of mature individuals) based on data from IUCN's "The IUCN Red List of Threatened Species". Version 2023-1. Retrieved from <https://www.iucnredlist.org> in March 2024.