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An early warning system for highly pathogenic viruses borne by waterbird species and related dynamics of climate change in the Caspian Sea region: Outlines of a concept

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Abstract

Aim. Formulation of the outlines of the concept of ViEW (**Vi**ral **E**arly **W**arning) which is intended as a long term system of multidisciplinary transboundary cooperation between specialist institutions of all five Caspian region states to research, regularly monitor and share data about the generation, transmission and epidemiology of avian-borne pathogens and their vectors in the region, and the ways climate change may affect these processes.

Material and Methods. The concept is based on the multidisciplinary experience of the authors in researching the processes incorporated in the ViEW concept and on an in-depth survey of the literature involved.

Results. The outlines of the ViEW concept are presented in this study for review and comment by interested parties and stakeholders.

Conclusion. Review of activities and opinions of specialists and organizations with remits relating to the development, establishment and maintenance of ViEW, indicates that such a system is a necessity for global animal and human health because of the role that the Caspian region plays in the mass migration of species of waterbird known as vectors for avian influenza and the already evident impacts of climate change on their phenologies. Waterbirds frequenting the Caspian Sea littorals and their habitats together constitute a major potential global hotspot or High Risk region for the generation and transmission of highly pathogenic avian influenza viruses and other dangerous zoonotic diseases.

Key Words
Caspian Sea, bird migration, avian influenza, surveillance, global hot spot, climate change impacts, early warning, high risk virus detection strategy.

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Система раннего предупреждения о высокопатогенных вирусах, переносимых водоплавающими птицами, и связанная с этим динамика изменения климата прибрежных районов Каспийского моря: основные положения концепции

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Резюме

Цель. Формулировка общих черт концепции ViEW (**Vi**ral **E**arly **W**arning – ранее предупреждение о вирусах), которая задумана как долгосрочная система междисциплинарного трансграничного сотрудничества между специализированными учреждениями всех пяти государств Каспийского региона для исследования, мониторинга и обмена данными о возникновении, передаче и эпидемиологии переносимых птицами патогенов, а также то, как изменение климата может повлиять на эти процессы.

Материалы и методы. Концепция основана на междисциплинарном опыте авторов в исследовании процессов, включенных в концепцию ViEW и на углубленном изучении соответствующей литературы.

Результаты. В этом исследовании представлены основные положения концепции ViEW для рассмотрения и комментирования заинтересованными сторонами.

Заключение. Обзор деятельности и мнений специалистов и организаций, имеющих полномочия, связанные с разработкой, созданием и поддержанием ViEW, свидетельствует о том, что такая система является необходимостью для глобального здоровья животных и человека, так как Каспийский регион играет большую роль в массовой миграции водоплавающих птиц, известных как переносчики птичьего гриппа, и уже очевидных последствий изменения климата для их фенологии. Водно-болотные птицы, посещающие прибрежные районы Каспийского моря, и их местообитания вместе представляют собой крупную потенциальную глобальную горячую точку или регион высокого риска образования и передачи высокопатогенных вирусов птичьего гриппа и других опасных зоонозных инфекций.

Ключевые слова

Каспийское море, миграция птиц, птичий грипп, эпиднадзор, глобальная горячая точка, последствия изменения климата, раннее предупреждение, стратегия обнаружения вирусов высокого риска.

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Prolegomena: Alignment with Priority Policies of the Russian Federation in Regard to Potential Biological Threats

On 25 March 2020, prior to the full understanding of the global pandemic danger presented by the COVID-19 coronavirus, Inger Anderson, Executive Director of the United Nations Environmental Programme (UNEP) warned: "*Nature is sending us a message*" *...Seventy-five percent of all emerging infectious diseases come from wildlife. Our continued erosion of wild spaces has brought us uncomfortably close to animals and plants that harbour diseases that can jump to humans. Human infectious diseas outbreaks are rising and in recent years there have been Ebole, bird flue, Middle east respiratory syndrome (MERS), Rift Valley fever, sudden acute respiratory syndrome (SARS), West Nile virus and Zika virus, all of which have crossed from animals to humans. Never before have so many opportunities existed for pathogens to pass from wild and domestic animals to people*". "*...We need to go into the future armed with nature as our strongest ally*".

In response to this situation, specialists at the Institute of Ecology and Sustainable Development od Dagestan State University and at the Federal Centre of Fundamental and Translational Medicine of the Siberian Branch of the Russian Acedmy of Sciencess have developed the concept of ViEW (**Vi**ral **E**arly **W**arning) responds to national strategic policies of the Russian Federation in a range of ways, particularly with regard to: "*International scientific and technical cooperation and international integration in the field of research and technology, which protect the identity of the Russian scientific sphere and state interests in the context of the internationalization of science and increase the effectiveness of Russian science through mutually beneficial international cooperation*" and "*the formation and promotion of the current scientific agenda of the state as a member of international organizations, increasing the level of participation of Russia in international systems of scientific and technical expertise and forecasting*". (Strategy of Scientific and Technological Development of the Russian Federation, 1 December 2016 No. 642), and also the implementation of the above as expressed in the Presidential address to the Russian Federal Assembly of 15 January 2020: "*I would like to stress that Russia is ready to support Russian and foreign scientists' joint research on ecology, climate change, environmental and ocean pollution. These are global development challenges shared by everyone*".

ViEW is intended as long term programme of multidisciplinary transboundary cooperation between specialist institutions of all five Caspian Sea littoral states to research, monitor (to an agreed methodology and regular schedule) and share data on the generation, transmission and epidemiology of avian borne pathogens in the Caspian region, with a particular emphasis on the ways climate change may affect these matters. In turn this information would be passed to those national, regional and international bodies which are tasked to incorporate and respond to such data within their respective global mandates.

The establishment of ViEW as an early detection and warning system for avian and inter-species viral transmission would also be a key component of the national scientific response to potential biogenic threats, as articulated in the Decree of the President of the Russian Federation of 11 March 2019 No. 97, "On the Fundamentals of the State Policy of the Russian Federation in the field of ensuring chemical and biological safety for the period up to 2025 and beyond". This policy has identified new priority areas in the field of ensuring chemical and biological safety, the main biological threats to Russia's security being considered to include modification of the properties and forms of pathogenic biological agents and the properties of their carriers; design and creation of pathogens using synthetic biology technologies and terrorist attacks associated with the use of hazardous biological substances.

Two of the Russian Federation's key viral research, monitoring and analytical centres in regard to biological threats posed by highly infectious animal-borne disease are located in Novosibirsk (Federal Centre for Fundamental and Translational Medicine, Siberian Branch, Russian Academy of Sciences) and in Makhachkala (Institute of Ecology and Sustainable Development, Dagestan State University) on the Caspian Sea coast, which would coordinate the ViEW programme.

ViEW would be established by agreement and in collaboration with the member institutions of the Association of Universities and National Research Centres of Caspian Region States, whose International Institute of Ecology and Sustainable Development of Universities and National Research Centres of Caspian Region States is directed by Director of the Institute of Ecology and Sustainable Development, Dagestan State University.

The endorsement and support of ViEW by the principal responsible international intergovernmental agencies (FAO, UNEP, WHO, UNESCO and WOAH) for ViEW would be sought, as would its structural incorporation into their regional and global strategies, in particular those relating to the Tehran Convention (Framework Convention for the Protection of the Marine Environment of the Caspian Sea) of which the Russian Federation is a signatory.

1. ViEW: Introduction

Prior to the COVID-19 pandemic, the most severe pandemic in modern human history was that of the highly contagious influenza outbreak of 1918-1920, which caused some 50 million deaths. Scientific opinions differ, but it may have been caused directly or indirectly by an H1N1 virus of avian origin. There are four main influenza virus species: A, B, C and D. Type A viruses are known to infect a wide variety of birds and mammals, while the other species have more restricted host ranges. Influenza A viruses (IAV) include all avian influnza viruses (Lycett, 2019). The first documented occurrence of highly pathogenic avian influenza in a wild bird population was in 1961, when an outbreak in Common Terns (*Sterna hirundo*) killed about 1,600 birds in South Africa. Current avian influenza viruses (AIV) have a fast mutation rate and virus strains have been circulating and diversifying in wild bird populations for more than a century. Exchange of genes between virus strains that co-infect cells in the same host, a process known as reassortment, further increases the evolutionary speed of the virus. Direct transmission of the virus from wild birds to humans appears to be very rare (or non-existent), presumably due to the low frequency of contact between the two populations; however, transmission from domestic avian

species to humans does occur, especially in live poultry (wet) markets in Asia. Already in the present century there have been a number of avian influenza outbreaks of concern, of particular virulence being the highly pathogenic HPAI H5N1 strain first reported in Central Asia and Eastern Europe in 2005 and continuing to spread into Europe and south west Asia in 2006-2007. In 2009 the "swine flu", a strain of H1N1 virus resulting from a reassortment of avian, swine and human influenza viruses, caused more than 284,000 fatalities globally (Lycett, 2019; Mehrabanpour et al., 2012).

Since the 2005 outbreak, increasing attention has been placed on researching and monitoring avian influenza viruses in both wild and domestic birds. Because some bird populations can travel long distances, there are high chances of AIV reaching a wider range of birds or other species. Waterbirds, especially those of the order Anseriformes, are known as a natural reservoir for avian influenza viruses (AIV) (Stallknecht 2003), with the viruses being most prevalent in dabbling (surface – feeding) ducks, especially Mallard (*Anas platyrhyncos*) (Olsen et al., 2006; Vandegrift et al., 2010). Certain gulls and terns are also identified as significant viral vectors.

New avian viruses and subtypes are generally documented as developing in east or south-east Asia, then spreading to Mongolia, Siberia and Europe and can cause extensive mortality in both wild birds and poultry. Migratory water birds mixing with domestic or farmed poultry may contribute to the generation of new viruses by reassortment which may eventually spread intra- and intercontinentally.

Migratory birds are also one of the best groups of animals to monitor for the effects of climate change, which may in turn impact on the generation and dissemination of new pathogens. Most birds are day-time active, conspicuous, easy to identify and are popular with many groups of people, including amateur birdwatchers and professional scientists (Ferrer et al., 2008). In the analysis of Ferrer and colleagues, "many parts of Europe and North America, particularly, their distributions and numbers, as well as the timing of their migrations and breeding seasons, have been well monitored for decades. Migratory birds are likely to be more vulnerable than non-migrants because they can influenced by conditions in three different geographic locations: their breeding grounds, their wintering areas, and their migration routes. A growing body of field and laboratory evidence indicates that, far from being a static and conservative trait, migration is a dynamic and flexible behaviour in birds that is greatly influenced by external factors. Thus we can expect that in addition to population effects in migrants, migratory behaviour, itself, is likely to change in association with climate change. And, indeed, many changes in migration already have been reported. Many migrants are migrating earlier in spring than formerly, and some are migrating later in autumn as well. Most examples of shifts of migratory behaviour involve species that have extended their breeding ranges into higher latitude areas where over-wintering was not possible or was highly risky in the past. On the other hand, some species that once were entirely migratory are now partially migratory, with increasing numbers of individuals staying on their breeding grounds year-round. In yet other species, individuals are now migrating shorter distances than formerly, and are over-wintering farther north" (Ferrer et al., 2008).

Accordingly, in the last two decades significant research internationally has been ongoing into the causes, vectors and epidemiology of AIV and the documentation of associated impacts of climate change. A considerable number and geographical scope of national, regional and global surveys of these inter-related phenomena have been undertaken. In North American and European countries, in particular, a significant body of epidemiological data has been gathered regarding the circulation of AIVs in wild birds. Nonetheless, little is known about the prevalence of AIVs in wild birds in West and Central Asian regions, where many countries have been severely affected by each successive wave of outbreaks (Marashi et al., 2020).

In some cases, surveys undertaken have been reactive, focusing on the reporting of birds found dead and the analysis of the biological cause of individual deaths (Fereidoini et al., 2010). In other cases work has been undertaken to attempt to forensically reconstruct from pre-existing monitoring and other data what may have led to the outbreak and spread of a particular outbreak (Delaney et al., 2006). There have also been a number of initiatives over an extended time period of time to monitor or collate monitoring data on species of waterbirds which research has shown to be primary vectors for avian influenza viruses. A good example of the latter approach is the Asia-Pacific Working Group on Migratory Waterbirds and Avian Influenza (APWG-MWAI) which was established under the auspices of the Asia-Pacific Migratory Waterbird Conservation Committee, the predecessor of the East Asian-Australasian Flyway Partnership and the Central Asian Flyway (CAF) Action Plan. The goal of the group is to coordinate, facilitate and promote collation of avian influenza-related waterbird programmes and activities in the East Asian-Australasian and the Central Asian Flyways.

Rarely, however, has there been instituted an integrated regional or global system to regularly monitor high risk waterbirds in the field over an indefinite future time span, although there are some exemplary exceptions.

The Caspian region is one of the potential global HPAI hotspots in Eurasia which requires just such a system of AIV surveillance, being located at the intersection of three major migratory routes: the Central Asian flyway, the East Africa/West Asian flyway and the Black Sea/Mediterranean flyway (Fig. 1). Due to the richness of its large saltwater bays, lagoons, river deltas and inland wetlands, the Caspian region represents a primary route for the seasonal migrations of many bird species in Eurasia. Ecological characteristics of these unique habitats allow wild waterfowl and shorebirds to use numerous Caspian wetlands for both wintering and nesting. Moreover, this region also provides staging sites for species that migrate further to and from Europe or Africa (Gulyaeva et al., 2021). As noted below, some waterbird species do not always fly either south or north through the Caspian region in their seasonal migrations but also westwards to Crimea and the western Black Sea coasts in particularly cold winters after passing through the northern Caspian region.

2. The ViEW concept

Through ViEW (**Vi**ral **E**arly **W**arning System) the intention is to establish and operate a long term programme of multidisciplinary transboundary cooperation between

specialist institutions of all five Caspian Sea littoral states to research, monitor (to an agreed methodology and regular schedule) and share data on the generation, transmission and epidemiology of avian borne pathogens in the Caspian region, with a special emphasis on the ways climate change may affect these processes. In turn this information would be passed to those national, regional and international bodies which are tasked to incorporate and respond to such data within their respective global mandates. A key body in this respect is the Scientific Task Force on Avian Influenza and Wild Birds which was co-convened by the Convention on the Conservation of Migratory Species of Wild Animals (CMS) and the Food and Agriculture Organization of the United Nations (FAO) in response to large-scale outbreaks of highly pathogenic avian influenza (HPAI) in wild birds. It works as a communication and coordination network that keeps under review the role of wild birds in the epidemiology of AI and the impact of the disease on wild birds, promoting a balanced opinion based on currently available evidence. Task Force members include FAO, CMS, the African Eurasian Waterbird Agreement (AEWA), BirdLife International, EcoHealth Alliance, International Council for Game and Wildlife Conservation (CIC), Ramsar Convention, Royal Veterinary College, Wetlands International, and Wildfowl & Wetlands Trust (WWT). Task Force observers include the United Nations Environment Programme, the World Health Organization and the World Organisation for Animal Health (WOAH).

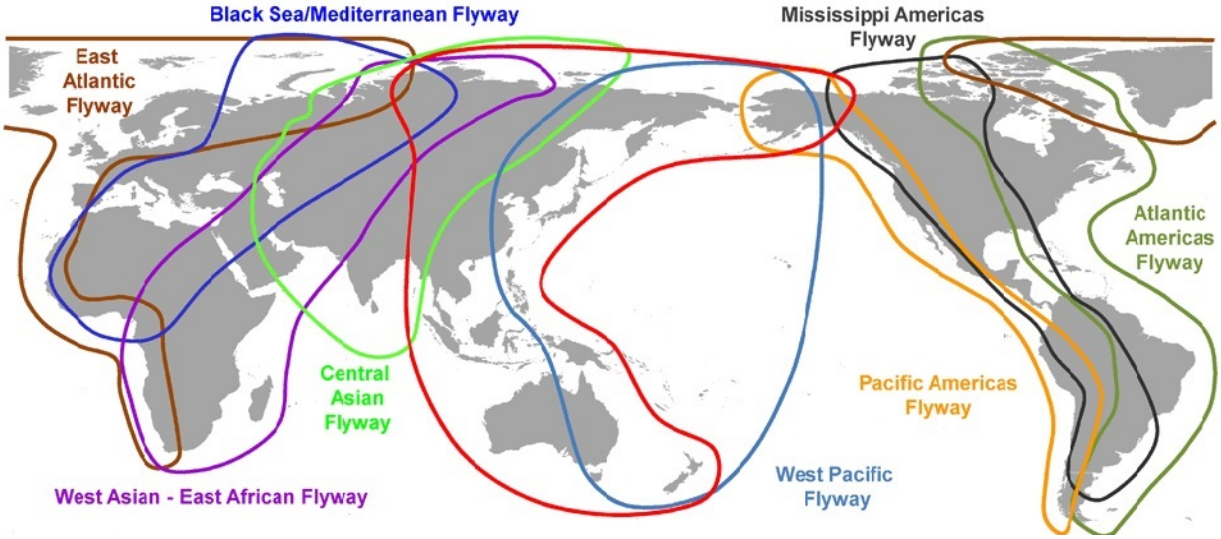

Figure 1. World migratory flyway zones

Another important international resource is the Global Consortium for H5N8 and Related Infuenza Viruses (GISAID) platform was launched on the occasion of the Sixty-first World Health Assembly in May 2008. Created as an alternative to the public domain sharing model, GISAID's sharing mechanism took into account the concerns of Member States by providing a publicly accessible database designed by scientist for scientist, to improve the sharing of influenza data. Since its launch GISAID plays an essential role in the sharing of data among the WHO Collaborating Centers and National Influenza Centres for the bi-annual influenza vaccine virus recommendations by the WHO Global Influenza Surveillance and Response System (GISRS).

2.1 Rationale behind the ViEW concept

The concept of ViEW is currently being developed by a Russian research team in Dagestan and Siberia to address the current overall deficit in systematic data for the Caspian Sea region by monitoring the presence and dynamics of viruses in waterbirds resident, wintering in or seasonally migrating through this potential global HPAI hotspot. Also important is the regular monitoring of threats to human and other mammalian health carried by waterbirds such as the West Nile virus (in Iran crows have been identified as vectors of this bird-mosquito borne malady (Sharti, 2020)), the schistosome parasite that causes cercarial dermatitis and heavy metals caused by anthropogenic pollution in the living environment of waterbirds

ViEW would also collect further information to understand and respond to the growing impacts of climate change on these birds and on critical aspects of the biodiversity of the Caspian and other regions they frequent. Parallel monitoring would be undertaken on the bat species inhabiting the region and the Caspian Seal, both of which have been identified as viral vectors.

The ViEW surveillance concept builds on the experience and activities of specialists of all Caspian Sea littoral states (Azerbaijan, Iran, Kazakhstan, Russia and Turkmenistan) within the policy framework of the Tehran Convention (Framework Convention for the Protection of the Marine Environment of the Caspian Sea), and particularly draws particularly on the scientific resources and networks of the International Institute of Ecology and Sustainable Development of the Association of Universities and National Research Centres of Caspian Region States.

As a response to the 2005 outbreak of the Avian Influenza Asian Lineage HPA1 H5N1 virus which spread from east Asia to south-west Siberia, the Kazakhstan and the Urals, the European Commission sponsored an “Urgent preliminary assessment of ornithological data relevant to the spread of Avian Influenza in Europe” by Wetlands International and EURING (European Union for Bird Ringing) (Delany et al., 2006). Migratory birds were suspected of playing a role in the spread of the disease which meant that the European Union could be under

direct threat as a number of waterbird species which were known as avian influenza viral vectors (geese, ducks and shorebirds in particular) were known to migrate through already infected areas in Eurasia and south-west Asia to the EU in winter. The aims of the project were: (1) to identify species which posed a relatively high risk of spreading H5N1 along their migration routes to the European Union, (2) to analyse the migration routes of these so-called Higher Risk Species on the basis of recoveries of ringed birds, (3) to identify wetland sites where Higher Risk Species concentrate in large numbers during migration and wintering and (4) to develop and test a format for the rapid assessment of ornithological data at the level of wetland sites, in order to prepare wetland managers and EU communities for an outbreak of H5N1.

The EU initiative's identification of Higher Risk Species focused on the Anseriformes (swans, geese and ducks) and the Charadriiformes (shorebirds, gulls and terns). Firstly, all species of both groups which occur in Europe and which are migratory were selected. Then each species was characterised on the basis of behavioural and ecological characteristics which were assumed to be related to the chance of becoming infected with H5N1 outside the territory of the EU. The characteristics chosen were habitat use, gregariousness and degree of mixing with other species. Species were selected which occurred in agricultural and/or freshwater habitats, which were highly gregarious and which showed a high degree of mixing, which led to a list of 26 Higher Risk Species being identified. Contact risk with poultry was also estimated, resulting in the highest scores for Mallard (*Anas platyrhynchos*) and the Black-headed Gull (*Larus ridibundus*).

Three maps (here Figs. 2-4) contained in the resulting published study (Delany et al., 2006) and replicated here indicate quite clearly why the Caspian region is of particular research significance with regard to waterbirds which are potential vectors for AIV and the useful potential role the implementation of the ViEW system could play in providing timely data on emerging viruses to the appropriate national and international health authorities and organisations.

Figure 2. (Fig. 2.1 in original publication) shows the locations of peak January counts between 1990 and 2000 of all species counted – once again the map shows that the south Caspian Sea area exceeded all other areas surveyed in Europe, Africa and West Asia

Figure. 3. (Fig. 2.3 in original publication) shows the number of 17 waterbird species considered to pose a Higher Risk of spreading avian influenza recorded at each International Waterbird Census site during its regular January counts between 1990 and 2005 in Europe, Africa, West and Central Asia. The map shows that the highest concentration of these species in the whole region surveyed was in the area of the south Caspian Sea

Figure 4. (Fig. 2.4 in original publication) shows the locations of all sites where combined counts of Higher Risk waterbird species exceeded 20,000 between 1990 and 2005 and where two or more of these species occurred in numbers exceeding thresholds of 100, 250 or 500 (depending on the species). The highest combined counts are in the south Caspian Sea area.

High Risk species of duck identified in this research were: Eurasian Wigeon, Common Teal, Mallard, Northern Pintail, Garganey, Northern Shoveler, Marbled Teal, Red-crested Pochard, Common Pochard and Tufted Duck. All these occur in the Caspian region, residing or migrating (Figs. 5; 6).

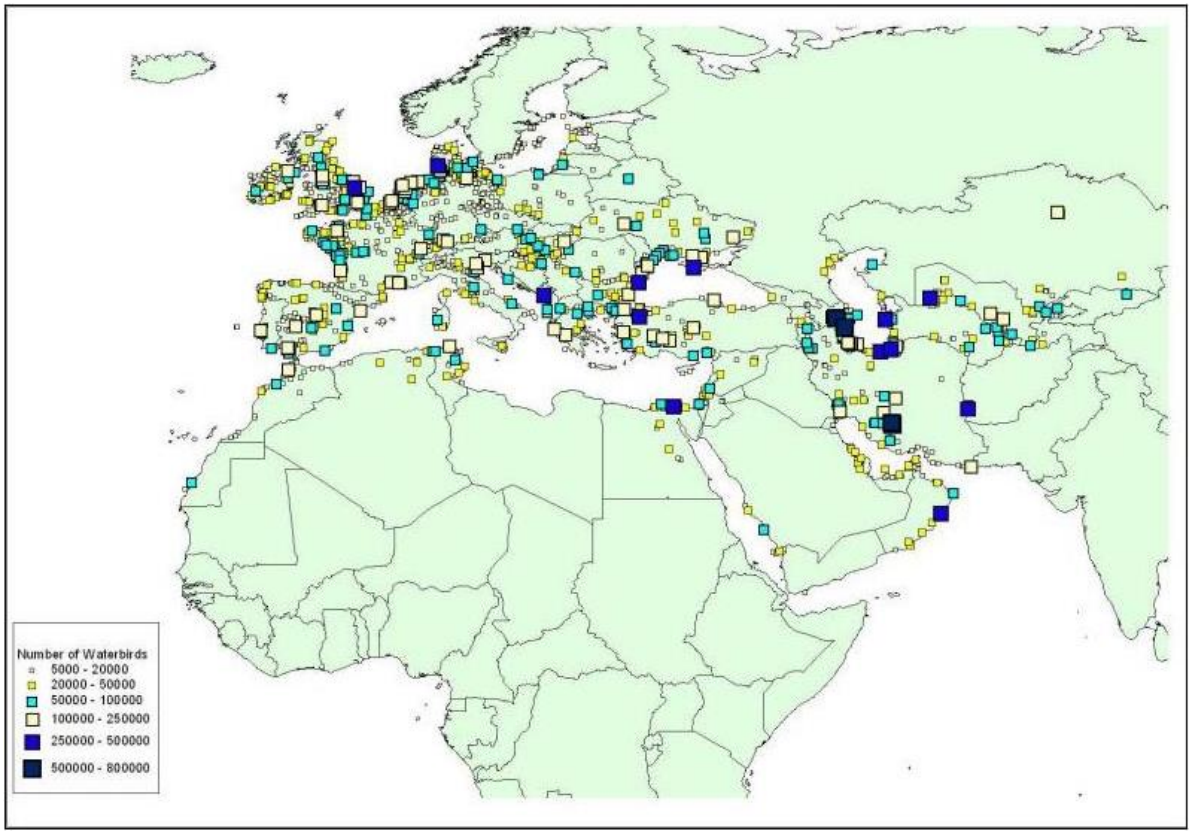

Figure 2. Peak January counts between 1990 and 2005 of all waterbird species combined (after Delaney et al., 2006 – Fig. 2.1)

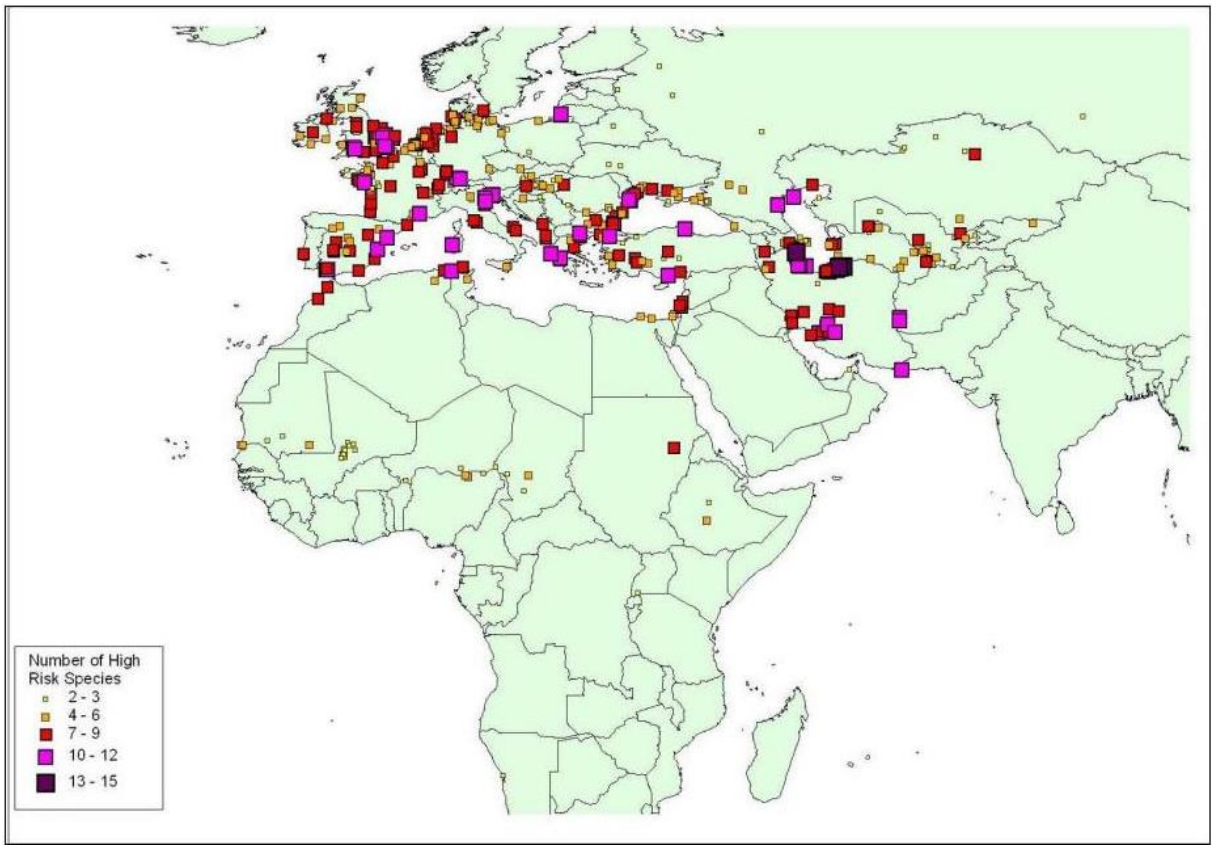

Figure 3. Number of 17 waterbird species considered to pose a High Risk of spreading Asian influenza recorded at each International Waterbird Census site during January counts between 1990 and 2005 in Europe, Africa, West and Central Asia (after Delaney et al., 2006 – Fig. 2.3)

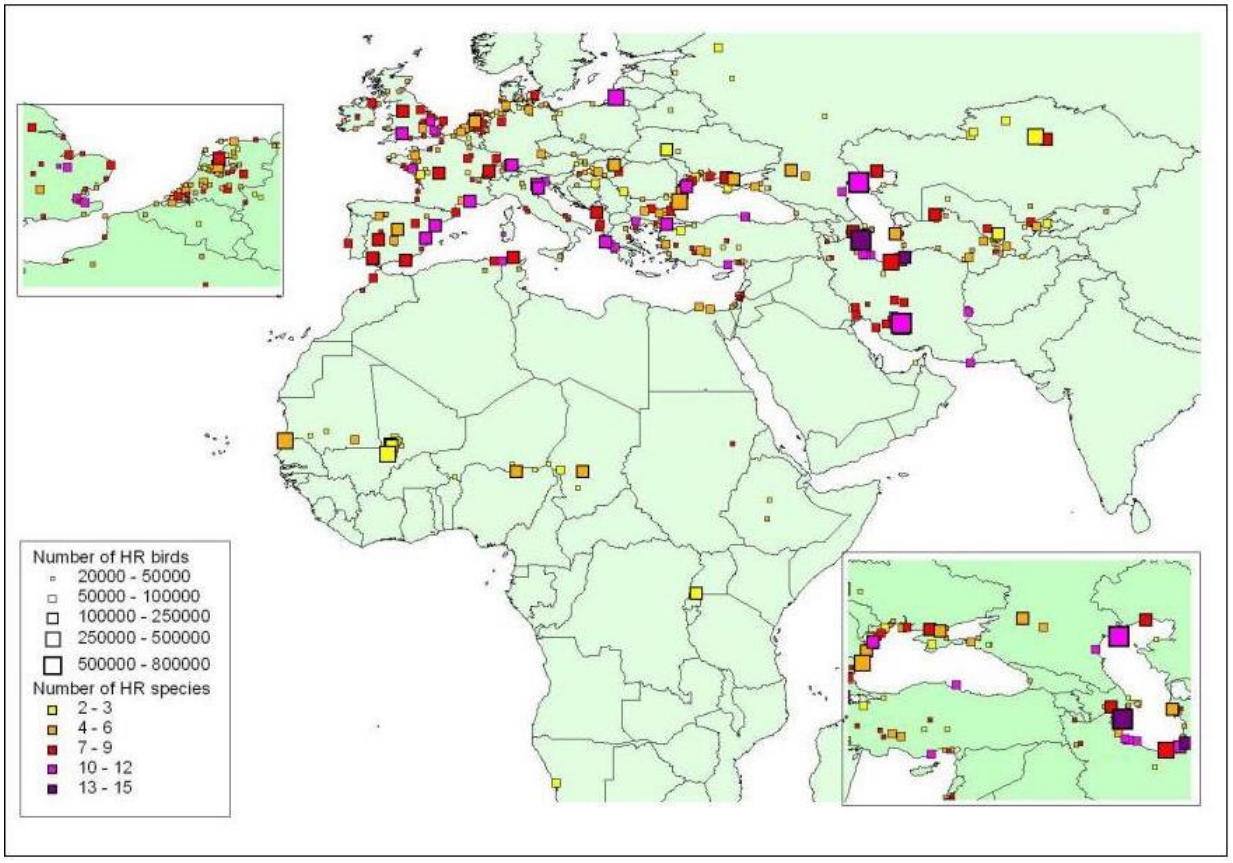

Figure 4. All sites where combined counts of High Risk waterbird species exceeded 20,000 between 1990 and 2005 and where two or more of these species occurred in numbers exceeding thresholds of 100, 250 or 500 depending on the species (after Delaney et al., 2006 – Fig. 2.4)

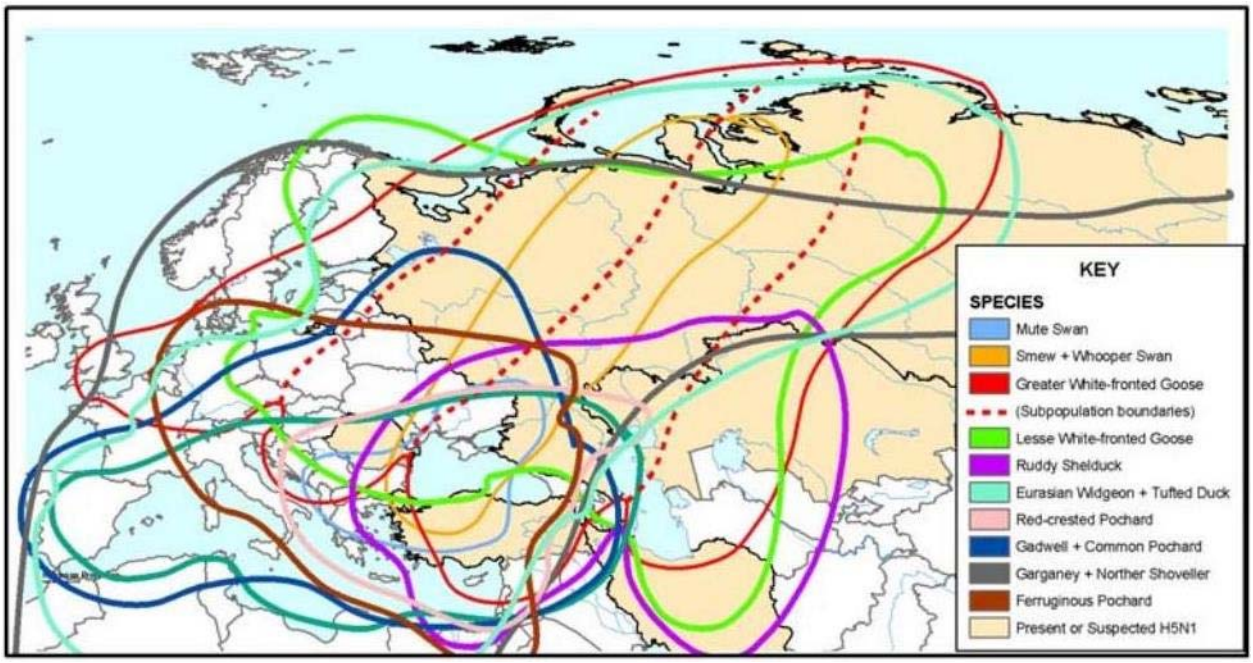

Figure 5. Map of migration zones in Europe and West Asia of certain individual waterbird species (after ArcGIS Development Team, March, 2000)

Figure 6. Main geographical populations of Anatidae in western Eurasia: (1) Northern White Sea/North Sea population; (2) European Siberia/Black Sea-Mediterranean population; (3) West Siberia/Caspian/Nile population and (4) Siberian-Kazakhstan/Pakistan India population (after Isakov, 1967; Boere & Stroud, 2006)

3. ViEW: Principal locations along the Caspian Sea littoral where waterbirds congregate as residents or migrants
(Fig. 7)
Note: The information in this section (3.1-3.3) has been compiled primarily from Ramsar data sheets on each of its sites, Birdlife International Datazone fact sheets on most sites, relevant UNESCO Biosphere reserve information and data from government information sources of the five Caspian region states.

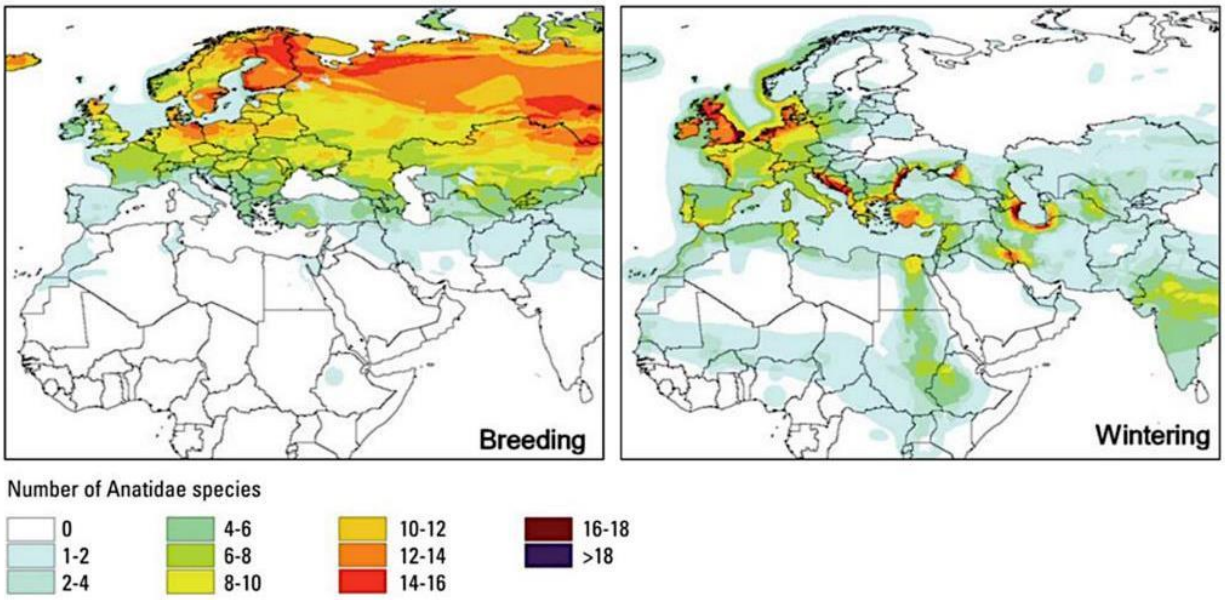

Figure 7. Map identifying the distribution of Anatidae breeding and wintering areas, colour coded according to number of species. As indicated in Figs. 2-4 above, there is a particularly high concentration of species in the winter in south Caspian littoral and inland wetlands from Dagestan in the west to Turkmenistan in the east (after Gilbert et al., 2008)

3.1. Western Caspian littoral:
Russia: Russia has many areas of ornithological significance. Birdlife International has identified 470 Important Bird Areas (IBAs) in European Russia and 137 in Central Asian Russia.

• Astrakhansky Nature Reserve in the outer Volga River delta. This general area is also registered as the Volga Delta Ramsar site and a UNESCO Biosphere Reserve. It is a staging area for migrating waterbirds, shorebirds, raptors and songbirds, which breed further north in the west Siberian Plain, north Kazakhstan and other northern latitudes and winter further south. The delta is one largest in the world and characterized by a highly braided morphology, creating over 1,000 channels in the lower delta. The protected areas are along its seaward edge and are composed of extensive areas of open water, numerous islands, reedbeds, and other aquatic plants. During mild winters, the delta supports up to 750,000 waterbirds, including swans, geese and ducks. Summer moulting ducks reach 400,000 individuals.

• Agrakhansky Federal Nature Reserve. While previously this was also primarily a stop-over point for migrating waterbirds flying south to winter and returning north in spring, rising temperatures in some recent winters have resulted in some waterbirds wintering there. These birds return north to breed in the spring.

• Kizlyar Bay on the Dagestan coast is one of the largest bays in the Caspian Sea and is also one of the largest migratory routes for waterbirds and other birds in Eurasia, connecting European parts of Russia, western Siberia and north Kazakhstan with Transcaucasia, western Asia, the Near East, North and East Africa. It is designated a UNESCO Biosphere Reserve and represents a diversity of marine, coastal and desert-steppe ecosystems. It holds three IBAs of global significance (IBA EU-RU419 "Nizhnekumskiye Floods", IBA EU-RU172 "Kizlyar Bay", and IBA BC 038 "Tyuleni Island"), two potential Ramsar sites ("Kizlyar Bay" and "Nizhnekumskiye Floods"). The entire water area of the biosphere reserve lies within the boundaries of a special North Caspian Protected Fishery Zone, the status of which is close to that of nature sanctuary.

• Turalinsky Lagoon (near the city of Mahachkala) and Turali 1 Lagoon (near the city of Kaspiisk). Despite being very close to major urban areas, these a significant stop-over sites for migrating waterbirds.

• Lake Aji-Papas. Located in the central coast of Dagestan, this wetland provides suitable habit and climatic conditions for some waterbirds to permanently reside there. Others migrate from the north to winter there (although some species which previously did this now sometimes winter in the Aghragansky wetlands further north). There also are species which winter further south but migrate north to breed in the Lake Aji-Papas wetlands.

Azerbaijan: There are a number of protected wetlands in Azerbaijan, where some waterbirds permanently reside, while some stop over on their passage further south and others winter there, returning north to breed in the spring. Birdlife International has identified 53 IBAs across the country. An important staging site for migrating birds is the topographical corridor of Besh Barmag on the coast north of the Absheron Peninsula. The greatest concentration of waterbirds in Azerbaijan occurs in the Gyzylagach Bay State Reserve. To its north are the Kura River delta reserve and some smaller sites along the north Azerbaijan coast, while inland there are a number of wetland reserves, among

them the Aggol National Park (a Ramsar site), the Sarisu lakes system in the Bilasur-Kurdamir area and Lake Urmiah, which are also important habitats for both resident and migratory waterbirds.

• The Gyzylagach State Reserve is one of the most important places for wintering and breeding waterbirds in the Western Palearctic. It comprises four main parts: (1) Great Gyzylagach Gulf and Little Gyzylagach Gulf; (2) a maritime belt of reed growth in Great Gyzylagach Gulf; (3) an extensive area of shallow waters and reeds; and (4) areas of semi-desert in the rest of the reserve. Despite the importance of this area it is under-surveyed, as the last counts took part in 1990, but it is estimated that about 500,000 waterbirds winter there. The reserve is registered as a Ramsar site.

• Birdlife International considers the Lake Sarisu area to be one of the best sites for waterbirds in the interior of Azerbaijan with some 70,000-150,000 wintering birds of which 90% are ducks. The site is a system of saline lakes with vast reedbeds with three areas of open water, a few small islands and shallows.

3.2. Southern Caspian Littoral

Iran: A number of major wetlands along the south Caspian Sea coast of Iran provide habitats for some resident waterbirds, while hosting very large numbers of wintering migrants and others in passage south as staging points. The principal coastal locations are (from west to east): Anzali Wetlands; Bujagh National Park; Amirkelayeh Lake; Fereidoun-Kenar Wetland, Miankaleh Wetland and Gomishan Lagoon adjacent to Turkmenistan. There are also a number of inland wetlands important to certain duck and other aquatic species. Birdlife International has identified 105 IBAs in the territory of Iran.

• Anzali wetland complex. This is located in Gilan province in the south-west corner of the Caspian Sea adjacent to the port city of Banda-e-Anzali. Parts of the wetland are protected as the Siakesheem protected area and Selke wildlife refuge. Other areas are mainly used for rice and vegetable crops and grazing. Registered as a Ramsar site, this is a large, freshwater lagoon fed by several rivers and separated from the sea by a dune system. It supports extensive reedbeds and abundant submerged and floating vegetation. Several perpetual streams emanating in the nearby Talesh Mountains feed into the Anzali complex. The permanent wetland is surrounded by seasonally flooded marshes and ab-bandans (man-made water impoundments for rice cultivation). Many of the ab-bandans surrounding the wetland are traditional managed as duck-trapping areas (damgah) throughout the winter months when they are intentionally flooded to attract (see below) (Vuosalo-Tavakoli et al., 2008). At these sites, the duck trappers employ a traditional hand-netting technique to catch ducks and coots dazzled by a bright light from a boat at night. Of great concern is that many ducks are also killed by shotgun (some 100,000 each year). The site is of international importance for breeding, staging and wintering waterbirds. Annual mid-winter waterfowl censuses have been carried out by the Ornithology Unit of the Department of the Environment since 1967. Many ornithological studies have been carried out at other times of the year, including comprehensive waterfowl censuses in mid-November in 1972, 1973, 1974, 1979, 1980, 1983, 1984, 1985, 1986 and a duck-ringing programme was initiated by the ornithology unit in 1974. The Department of the Environment has also carried out investigations on duck-hunting in the wetland, and on the invasive spread of *Azolla*, an introduced floating water fern which is suppressing native flora which is important food for waterbirds. The Department has established 35 monitoring stations throughout the wetland, to measure a variety of parameters, including changes in water level, water quality and physico-chemical characteristics. Excellent research facilities are available at the nearby town of Bandar-e Anzali.

• Bujagh National Park is a Ramsar site on the delta of the Sefid Rud River in Gilan Province. The park includes different types of important ecosystems having two large lagoons (the Bujagh and Kiashahr), the Sefid Rud River (the second largest river in Iran) and its flooded plains, the deltaic system (the largest in the south Caspian), sandy shoreline and marine ecosystem and some rice fields. Kiashahr Lagoon is a shallow sea bay which once linked the freshwater and brackish marshes and the nearby riverine marshes at the mouth of the Sefid Rud but is now open to the sea. There are also open grassy areas and dunes near the mouth of the river. The site is important because of its wide variety of waterfowl. It is registered as a Ramsar site.

• Amirkelayeh Lake is located on the coastal plain in Gilan province. It is a rather deep, permanent, coastal freshwater lake with rich floating and submerged vegetation, extensive reed-beds and some willow thickets. The water is very clear and it is one of the few freshwater wetlands located near the Caspian Sea. The wetland provides a suitable habitat for mostly migratory species and is important for several species of wintering waterbirds, mostly Anatidae (ducks, geese, swans, etc.), including the endangered white-headed duck (*Oxyura leucocephala*). It is registered as a Ramsar site.

• Fereidoun-Kenar, Ezbaran and Sorkh Ruds Ab-Bandans. This Ramsar site is an artificially created wetland in the South Caspian lowlands, 5km south of the town of the same name and 13 km southwest of Babolsar in Mazandaran province. The site is comprised of damgah surrounded by forest strips and reedbeds. The area is of outstanding importance as wintering grounds for the entire western population of the Siberian Crane (*Grus leucogeranus*), listed as 'critically endangered' in the IUCN Red Book. Apart from rice farming the land is used for forestry and fishery. As in the Anzali wetlands, an important traditional activity is duck trapping in damgah (Vuosalo-Tavakoli et al., 2018), long a main source of income during the winter months through the sale of the birds in local live poultry markets. In the past at the end of each duck trapping season the area was opened up for gun hunting in a massive "shoot-out", creating a potential threat for Siberian Cranes to be shot accidentally, but in 2001 the Department of Environment designated the whole site as a Non-Shooting Area. Conservation measures include annual mid-winter waterfowl censuses and a MoU on Siberian Cranes with 9 'range states' of the Convention on Migratory Species. A GEF project, implemented through UNEP and coordinated by the International Crane Foundation and CMS, aims to conserve the critical sites used by Siberian Cranes for breeding, staging during migration, and the main wintering grounds.

• Miankaleh, Gorgan Bay and Lapoo-Zaghmarz Ab-bandan: Just to the east of the city of Miankaleh in the province of Matandaran there is a brackish bay almost completely cut off from the sea, which supports freshwater marshes and seasonally flooded woodland, and a freshwater lagoon supporting extensive reedbeds. Gorgan

Bay is a shallow, brackish embayment, almost cut off from the Caspian Sea by Miankaleh Peninsula, a 60 km long sand dune ridge, partly covered by grassland and scrubs. The bay receives freshwater inflow from a number of small rivers and streams rising on the humid northern slopes of the Alborz Mountains. Some freshwater marshes occur at the western end of the bay, where freshwater input is greatest. The Lapoo-Zaghmarz Ab-bandans are long, narrow freshwater lagoons located at the landward end of Miankaleh Peninsula, about 10 km west of Gorgan Bay. The Miankaleh Peninsula, Gorgan Bay and Lapoo-Zaghmarz Ab-bandan are together designated a UNESCO Biosphere Reserve and a Ramsar site. They constitute an extremely important for area for breeding, passage, nesting and wintering of many waterbirds including species identified as AIV vectors.

- Gomishan Lagoon: Situated in Golestan province in the south-east corner of the Caspian Sea and at the edge of the Turkmen steppe, this lagoon is separated from the sea by a narrow sandy barrier which is frequently overrun by the sea. It is an important area for the breeding, passage, nesting and wintering of many waterbirds including species identified as AIV vectors. It is registered as a Ramsar site.

3.3. Eastern Caspian Littoral

Turkmenistan: A number of waterbirds migrate along the east coast of the Caspian Sea to winter in Turkmenistan or use its bays and wetlands as staging points on the Afro-Eurasian flyway and part of the Central Asian-Indian flyway along the Caspian Sea coast and via four small reservoirs (Saryyaznskoye, Zeid, Oguzkhan and Sarykamysh). Turkmenistan has designated two disjoined coastal sectors of the country as the Khazar Nature State Reserve, which is currently on the UNESCO World Heritage Tentative List.

- Khazar State Nature Reserve. The conservation zone of the reserve includes all areas of water of Turkmenbashi and North-Cheleken Bays, a buffer zone of salt marshes around them, North-Cheleken spit, islands in Michailov Bay and Dag-Ada Island in the north-east corner of Turkmenbashi Bay. In 1994 a large island in the Caspian Sea, known as the Ogurchinsky State Sanctuary, was included in the reserve. The Khazar State Nature Reserve was previously (1968-1994) known as Krasnovodsky State Nature Reserve. The reserve and its sanctuaries are under the management of the Ministry of Agriculture and Environmental Protection of Turkmenistan. In 1978 the reserve was designated a Ramsar site. The reserve is classified as an Important Bird Area (IBA) and is located on one of the most important migratory flyways for waterbirds breeding in western Siberia, Kazakhstan and other regions of Central Asia, providing a valuable stopover and wintering site. The Khazar State Nature Reserve can only be compared in size and importance with the Gyzylagach State Nature Reserve in Azerbaijan and the Miankaleh State Nature Reserve in Iran. Birdlife International has identified 50 IBAs in the territory of Turkmenistan.

Within the Khazar State Nature Reserve, Turkmenbashi Bay encompasses several shallow brackish bays, spits, islands and dunes. About 5-8 million waterbirds pass along the east coast of the Caspian Sea on migration and up to 0.8 million winter in Turkmenbashi Bay. It is thus the largest wintering area for waterbirds that nest in western Siberia, Kazakhstan and other regions of northern Asia. It is registered as a Ramsar site.

In 2018, The Norwegian Institute of Nature Research (NINA) issued a report on the status of the wildlife of Turkmenistan (NINA 2018), in which was stated, “The general impression is of a quite healthy bird fauna and a very low level of impact of agriculture chemicals or other pesticides on the wildlife in general. Most of the habitats appear to be in good condition. Although the avifauna seems to be in a good situation there appears to be very little investment in monitoring or protection of birds. This avian diversity makes Turkmenistan a potentially attractive birdwatching destination. Trip reports of birdwatchers can fill out the very significant gaps of bird information for most of the territory of the country and can contribute to better preservation of the bird fauna. Even more valuable can be some research projects between Turkmenistan experts and research institutes from Europe, targeting specific areas or scientific questions”.

“International co-operation in the sphere of biodiversity conservation within Turkmenistan is mainly implemented via UNDP. There are also some proposals from UNEP, TACIS, and the World Bank, which have only recently become more specific and turned into the form of real projects. The most significant projects are the National Environmental Action Plan for Turkmenistan (NEAPT) and Capacity-21. Regional co-operation is mainly of a data-sharing character, though biodiversity problems were touched upon in the Nukus and Almaty Declarations at the level of the Ministers of Environment. Several existing regional projects should be mentioned: the Aral Sea Project (World Bank, UNDP) and the “Biodiversity” component of the Caspian Ecological Program (CEP). Various Central Asian projects are at the stage of development and approval”.

Kazakhstan: Kazakhstan has many wetlands of importance to waterbird and other species, most of which are situated in the far north or east of the nation’s territory. One site, Saryarka, has up to 2 million birds breeding in its wetlands. The Saryarka steppe and lakes of Northern Kazakhstan are designated a UNESCO natural World Heritage Site and comprise two protected areas, the Naurzum State Nature Reserve and the Korgalzhyn State Nature Reserve. Here there are wetlands of outstanding importance for migratory waterbirds which are key stop-over points and crossroads on the flyways from Africa, Europe and South Asia to their breeding places in western and eastern Siberia. The site includes two groups of fresh and salt water lakes situated on a watershed between rivers flowing north to the Arctic and south into the Aral-Irtysh basin. Kazakhstan has 127 IBAs.

There are three state designated wetland reserve areas on Kazakhstan’s north-east Caspian Sea littoral, which, however, because of low temperatures and ice in winter (excepting sections of Lake Karakol), mainly function for waterbirds as staging points as they migrate further south for winter and return in spring to breed further north:

- Lake Karakol is located 10 km south-east of the city of Aktau. It is an artificial reservoir in a natural depression close to the Caspian Sea coast employed as a water settling basin of the Mangistau nuclear power plant since 1967 (according to other sources, it was created in 1968 as a result of the flooding of the Karakolshor salt marsh by waste waters of industrial enterprises in the city of Aktau). As a result, an extensive shallow reservoir with

numerous islets was formed. These and the western lake shore are overgrown with reeds. This created favourable conditions for nesting, wintering and resting on migration for a range of waterbirds. Where warm waters are discharged from the power plant the reservoir does not completely freeze even in the coldest winters. It is a specially protected natural area of the Karagiye-Karakol state zoological reserve of republican significance, created in 1986. Lake Korakol is classified by Birdlife International as an Important Bird Area.

- Lower reaches of the Emba River which flows into the Caspian Sea.
- Ural River delta (near the city of Atirau). The delta and adjacent Caspian Sea coast are designated as a Ramsar site and are part of Kazakhstan's North Caspian Nature Reserve. The wetland comprises a large variety of marine/coastal and inland wetland types. Due to its mixed water supply and seasonal variation, the site has a range of marine and freshwater habitats and supports considerable numbers and diversity of species. The site is significant for large numbers of nesting, moulting and migratory species, among them appreciable numbers of Mallard (*Anas platyrhynchos*) (12,000) and Eurasian Teal (*Anas querquedula*) (44,000).
- Tyuleni Archipelago. The islands are desert-like and sandy, with little grass. There are reeds on the leeward side of Kulaly Island as well as on the other islands, which are much lower and waterlogged. In past centuries many Caspian seals frequented the islands' shores, hence the name of the group. The islands are classified by Birdlife International as an Important Bird Area and declareded by Kazakhstan as a National Protected Zone (State Reservation). There are large concentrations of seagulls and wetland birds, like coots, wild ducks, swans, egrets, and waders in the archipelago during their nesting period. The Tyuleniy Archipelago is also an important breeding ground for the Sandwich tern (*Sterna sandvicensis*).
- Eastern sector of Volga River delta. The site consists of areas of inundated flatland with prolific reed growth. The mosaic of waterbodies (pools, large areas of open water, channels etc.) and reedbeds is typical for a large freshwater estuary. Several canals run seawards and are interspersed, in their turn, by channel-like connections. Terrestrial sections of the shore support stands of flood-forest. The wetlands are classified by Birdlife International as an Important Bird Area and states that the overall number of migrating waterfowl significantly exceeds 20,000 individuals but that precise supporting data is scarce.

4. ViEW: Research undertaken on Caspian Sea waterbirds and on specific avian pathogens identified in the region

Azerbaijan: The principal research activity being undertaken on the ecology of waterbirds resident in or migrating to or through Azerbaijan is being undertaken by the working group for ornithology of the Laboratory of Terrestrial Vertebrates of Institute of Zoology of the Azerbaijan National Academy of Sciences (headed by E.H. Sultanov). An ongoing project is the study of winter ornithological complexes of Azerbaijan in order to identify principal threats and to determine systematic responses to them. Work on avian influenza the monitoring of avian influenza and other epizootic diseases is undertaken within the laboratories of the Azerbaijan State Veterinary Control Service (SVCS) (see below).

Since 2006, the Azerbaijan SVCS has conducted an annual serosurveillance program for AI H5 and Newcastle Disease in which all 12 regional Zonal Veterinary Laboratories (VLs) participate. Each Zonal Veterinary Laboratory is responsible for collecting samples from 4 to 5 districts to ensure that surveillance occurs throughout the country. Field veterinarians collect serum samples from domestic fowl, and tissue samples are collected from dead wild birds in Azerbaijan's national parks and nature reserves (Zeynalova et al., 2015).

Iran: Iranian scientists and institutions have undertaken and continue to engage in extensive activities relation to the research, surveillance, sampling, prevention and response to zoonotic infectious diseases throughout the country, references to which are included in the bibliography below. Many key publications are in English.

Four articles providing a useful insight into the scientific evolution and direction of this work in Iran are those of Fereidouni et al. (2005a, 2005b), Nourani et al. (2015), Modiri Hamadan et al. (2021) and Mehrabadi et al. (1397 AH).

The latter study by Mehrabadi et al., stressed the economic and public health challenges posed by HPAI carried by resident and migratory waterbirds and identified over 300 wetlands, natural and artificial lakes and ponds in Iran which they frequent. It noted a wide range of weaknesses in the nation's responses and attitudes and considered that addressinging thess challenge requires national determination, higher organizational supervision, collaborative and practical cooperation of related organizations, and short and long-term planning based on the realities of the country. Modiri Hamadan et al. (2021) noted the dangers of transmission of pathogens posed by the sale of wild migratory aquatic birds at live poultry markets (a traditional fresh meat source) and the need for proper controls. Nourani et al. (2015) provide an overview of threats to Anatidae in Iran.

Kazakhstan: As noted above, the main wetlands where waterbirds congregate in Kazakhstan are in lakes and wetlands in the north of the country where they nest in summer. Kazakhstan's north-east Caspian Sea waters and coast freeze in winter and thus have no year round resident waterbirds although they constitute a significant stopping point for waterbirds migrating to and from warmer southern wintering points further south.

Nevertheless, there is a good body of work relating to the surveillance and laboratory analysis of avian influenza viruses and paramyxoviruses of the wild birds of Kazakhstan (Karamendin et al., 2014; Sultankulova et al., 2022). The latter study investigated the transmission of closely related strains or identical subtypes of AIVs by a flock-unit of migratory birds or annual cyclical pattern of subtype dominance. The finding of the simultaneous circulation of genome segments of the Asian, European and Australian genetic lineages of H3N8 AIVs in wild birds in Kazakhstan indicated the important role of Central Asia as a transmission hub of AI viruses linking the East Asian migratory flyways with European flyways and vice versa.

Russia: A considerable body of research applicable to the implementation of ViEW concept has already been published by the Russian team currently engaged in its development. A group of the partners involved from the Federal Centre for Fundamental and Translational

Medicine of the Siberian Branch of the Russian Academy of Sciences has considerable experience in the long term AI–related surveillance of wild birds. For example, they have undertaken a 10-year monitoring programme (2006-2016) on Uus Nuur Lake in Siberia (Shestopalov et al., 2016) and are currently engaged in an Russian Science Foundation financed investigation of viral metapopulations in migratory birds of the Asian part of Russia and China for the early detection of new variants of viral pathogens (RNF Project No. 23-44-0026). A number of their studies have been published in English. One by Iverson et al. (2011) describes the sporadic transmission of H5N1 avian influenza virus from east to west via the migratory movements of waterfowl in Central Asia. Waterbirds in the genera *Anas* and *Tadorna* are suspected as vectors in the long-distance transmission of this highly pathogenic virus (Fig. 6). The former Soviet Republics of Central Asia are situated at important migratory crossroads for these and other species of birds that bridge regions where the disease is prevalent. However, waterfowl movements through Central Asia are poorly quantified. In the study by Iverson et al., historical data derived from over 80 years of bird ringing were combined with recent satellite tracking data to delineate migration routes, movement chronology and habitat use patterns of waterfowl in relation to H5N1 outbreak locations. The results have confirmed migratory linkage between breeding and moulting areas in northern Kazakhstan and southern Siberia, with non-breeding areas in the Caspian, Black and eastern Mediterranean Sea basins, as well as with South Asia. However, unlike the situation in neighbouring regions, most notably western China, H5N1 outbreaks have not been recurrent in Central Asia since they were first reported during summer 2005 and spring 2006. These findings have implications in relation to potential sampling biases, species-specific variation in migratory behaviour and continuing regional H5N1 transmission risks.

Another study by Shestopalov et al. (2022) provides a useful overview of wild animal migration as a potential threat of introduction of new viruses into Russia, while an article by Sharshov et al. (2019) reports the results of a study into the characteristics and phylodynamics of reassortment H12Nk viruses in northern Eurasia. During a 10-year long period of surveillance, Sharshov and his colleagues isolated five rare H12N5 and one H12N2 viruses in three different distinct geographic regions of Northern Eurasia and studied their characteristics. Wild waterfowl birds are known to be the main reservoir for a variety of avian influenza viruses of different subtypes but some subtypes, such as H2Nx, H8Nx, H12Nx, and H14Nx, occur relatively rarely in nature. H12N2 from the Far East region is a double reassortant containing hemagglutinin (HA), non-structural (NS) and nucleoprotein (NP) segments of the American lineage and others from the classical Eurasian avian-like lineage. H12N5 viruses contain Eurasian lineage segments. The researchers therefore suggest a phylogeographical scheme for reassortment events associated with geographical groups of aquatic birds and their migration flyways. The H12N2 virus is of particular interest as this subtype has been found in common teal in the Russian Far East region, and it has a strong relation to North American avian influenza virus lineages, clearly showing that viral exchange of segments between the two continents does indeed occur. The results of the research emphasize the importance of AIV surveillance in Northern Eurasia for the annual screening of virus characteristics, including the genetic constellation of rare virus subtypes, in order to understand the evolutionary ecology of AIV.

The work of Gulyaeva et al. (2021) focused on the Caspian Sea region to understand what genetic reservoirs are present there and to determine the biological properties and genetic characterization of novel low pathogenic H7N3 avian influenza virus isolated from Mallards in Dagestan. As already noted, wild ducks, in particular mallards (*Anas platyrhynchos*), have been recognized as key reservoir hosts in which most AIV subtypes are maintained by migratory and/or resident bird populations. It is supposed that bird movements are minimally affected by low pathogenic (LP) AIV infection, consequently resulting in the potential for virus shedding, spread, and reassortment during stopovers along the migration route. The study stresses tha the precise role of migrating and resident birds in amplifying and dispersing AIV is poorly understood, and in some occurrences, migratory birds can reinforce local circulation of AIV in resident populations. Shifts from intraspecies to interspecies transmission and gene reassortment events represent additional aspects of AIV's evolutionary strategy, enabling viral gene flow during the annual cycles of migratory behavior among wild bird species.

Considering the emergence of HPAI subtypes, studies on AIV ecology in natural ecosystems are of particular importance to better identify emerging health risks associated with wild bird reservoir hosts. As noted above, the Caspian region is one of the key points for AIV surveillance in Eurasia, being located at the intersection of three major migratory routes: the Central Asian flyway, the East Africa/West Asia flyway and the Black Sea/Mediterranean flyway. To understand AIV in the ecological context of the Caspian region, the researchers conducted surveillance efforts in both wild birds and poultry and analyzed sequence data from an evolutionary perspective. Two new viruses of H7N3 subtype were isolated from Mallards from which samples were taken in wetlands on the central coast of Dagestan. Although Caspian wetlands are the nesting, wintering and stopover grounds of a great number of migrating waterfowl, according to the available literature the isolation of the H7 AIV subtype seems to be a quite rare event in Caspian region in particular and in Russia in general. The molecular and biological properties as well as the pathogenicity characteristics of these new AIV strains were analysed in this study.

The findings of this work suggest that H7N3 viruses may frequently undergo reassortment and can be a natural recombinant that includes viral gene segments shared with both LPAIV and HPAIV. Thus, the results highlight the need for continuous and intensive surveillance of avian influenza in this region, with very active intersection of wild bird flyways suggestive of the exchange of AIV genes in a multi-host reservoir over a wide swathe of Eurasia (Gulyaeva et al., 2021).

Here the field work of ornithologists from the Russian and the other four Caspian region states should be highlighted for their great contribution to our knowledge of its waterbird species, notably that of E.B. Vilkov in Dagestan, who has emphasized issues relating to both antropogenic degradtations and threats to habits and the effects of climate change on species both resident and migratory (Vilkov 2016), Every state has its own ornithological society, each of which plays a most valuable role in documenting bird life in all its aspects. An important

regional organization in regard to the potential implementation of the ViEW concept is the Ornithological Society of the Middle East, Caucasus and Central Asia (OSME).

Turkmenistan: Scientific research into pathogens carried by birds in Turkmenistan is limited, although there is a legacy of valuable data on the country's natural history and ecology from the Soviet period. The Ministry of Agriculture and Environmental Protection has a National Institute of Deserts, Flora and Fauna which provides scientific support.

In 2018, The Norwegian Institute of Nature Research (NINA) issued a report on the status of the wildlife of Turkmenistan (NINA 2018), in which was stated, "Although Turkmenistan supports many wildlife species, there is very little up-to-date and accessible information about its status. ... The general impression is of a quite healthy bird fauna and a very low level of impact of agriculture chemicals or other pesticides on the wildlife in general. Most of the habitats appear to be in good condition. Although the avifauna seems to be in a good situation there appears to be very little investment in monitoring or protection of birds. This avian diversity makes Turkmenistan a potentially attractive birdwatching destination. Trip reports of birdwatchers can fill out the very significant gaps of bird information for most of the territory of the country and can contribute to better preservation of the bird fauna. Even more valuable can be some research projects between Turkmenistan experts and research institutes from Europe, targeting specific areas or scientific questions".

"International co-operation in the sphere of biodiversity conservation within Turkmenistan is mainly implemented via UNDP. There are also some proposals from UNEP, TACIS, and the World Bank, which have only recently become more specific and turned into the form of real projects. The most significant projects are the National Environmental Action Plan for Turkmenistan (NEAPT) and Capacity-21. Regional co-operation is mainly of a data-sharing character, though biodiversity problems were touched upon in the Nukus and Almaty Declarations at the level of the Ministers of Environment. Several existing regional projects should be mentioned: the Aral Sea Project (World Bank, UNDP) and the "Biodiversity" part of the Caspian Ecological Program (CEP). Various Central Asian projects are at the stage of development and approval".

5. ViEW: Organizational Structure, Surveillance Regime and Laboratory Analysis

5.1 Organisational Structure

ViEW activities are conceived as being undertaken with the coordination of the International Institute of Ecology and Sustainable Development of the Association of Universities and National Research Centres of Caspian Region States, whose Director also heads the Institute of Ecology and Sustainable Development of Dagestan State University in Makhachkala.

5.2 Surveillance Regime

In this regard, in 2019 Alekseev et al. published an analysis of the wetlands of the Republic of Dagestan in order to justify the selection of the collecting sites for material from migratory aquatic and semi aquatic birds in order to monitor the influenza A virus. The sites identified were wetlands of Lake Aji (Papas), Lake Yuzhny Agrakhan, Agrakhansky Gulf, the Terek River delta and the artificial Achikolsky lake systems west of the Agrakhansky Reserve.

The other primary potential surveillance and sampling points around the Caspian region which have been identified as hosting considerable numbers of waterbirds of the species considered as the primary carriers of viruses are: Azerbaijan – Gyzylagach Bay Nature Reserve; Iran – Anzali Wetlands and Miankaleh Reserve; Kazakhstan – Ural River Delta Reserve; and Turkmenistan – Khazar State Nature Reserve.

To an agreed regular annual schedule and sampling methodology, representatives of each sentinel organization would take a standard numbers of samples from one or more specific species in these locations, together the recording of related phenological and ecological data. They would also undertake other documentation relating to the impacts of climate change which would contribute to meeting ViEW's objectives.

5.3 Laboratory analysis

Due to the constantly evolving nature of influenza viruses, the World Health Organisation maintains a Global Influenza Surveillance and Response System (GISRS). It emphasizes the importance of global surveillance to rapidly detect virological, epidemiological and clinical changes associated with circulating influenza viruses that may affect human (or animal) health together with timely virus sharing for risk assessment.

The WHO states that "thorough investigation of all potential novel influenza human infections is warranted. All human infections caused by a novel influenza subtype are notifiable under the International Health Regulations (IHR), and State Parties to the IHR are required to immediately notify WHO of any laboratory-confirmed case of a recent human infection caused by new influenza A subtype with the potential to cause a pandemic. Evidence of illness is not required".

"In the case of a confirmed or suspected human infection, a thorough epidemiologic investigation of history of exposure to animals, of travel, and contact tracing should be conducted, even while awaiting the confirmatory laboratory results. The epidemiologic investigation should include early identification of unusual respiratory events that could signal person-to-person transmission of the novel virus. Clinical samples collected from the time and place that the case occurred should be tested and sent to a WHO Collaboration Center for further characterization" (WHO, 2011).

The Scientific Task Force on Avian Influenza and Wild Birds recommends that authorities with responsibility for animal health should apply One Health approaches for communicating and addressing avian influenza. That means recognizing that the health of humans, domestic and wild animals, plants, and the wider environment are interlinked and acting with a coordinated and unified approach. A One Health Joint Plan of Action was launched in 2022 by the Quadripartite – the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP), the World Health Organization (WHO), and the World Organisation for Animal Health (WOAH).

In all countries of the Caspian region except Iran and Russia, the presence of avian influenza in birds is viewed as best detected and monitored by specialist and central laboratories of the state veterinary service of each country, including National Reference Laboratories. Now that the Association of Universities of Caspian Region

States has now incorporated National Research Centres within its organisation, the various state veterinary service laboratories of the region would be the appropriate bodies to undertake the regular analyses of samples gathered as part of the ViEW system. Through ViEW the veterinary faculties in universities would also be involved, as would those higher educational institution faculties of medicine which specialise in epizootic infectious diseases.

Azerbaijan: Motahhar et al. (2022) report that following the appearance of influenza A/H5 virus infection along the Caspian Sea coast near Baku in several wild and domestic bird species in February 2006, two clusters of potential human avian influenza due to A/H5N1 (HPAI) cases were detected and reported by the Ministry of Health (MoH) to the World Health Organization (WHO) Regional Office for Europe during the first two weeks of March 2006. That same month the WHO led an international team, including infection control, clinical management, epidemiology, laboratory, and communications experts, to support the Azerbaijan MoH in investigation and response activities. The investigations revealed eight cases with influenza A/H5N1 virus infection confirmed by a WHO Collaborating Centre for Influenza and one probable case for which samples were not available. The cases were in two unrelated clusters in Salyan and Tarter districts. Close contact with and the de-feathering of infected wild swans were considered to be the most plausible sources of exposure to influenza A/H5N1 virus in the Salyan cluster. These cases constitute the first outbreak worldwide where wild birds were the most likely source of influenza A/H5N1 virus infection in humans. The rapid mobilisation of resources to contain the spread of influenza A/H5 in the two districts was achieved through collaboration between the MoH, WHO and its international partners. Control activities were supported by the establishment of a field laboratory with real-time polymerase chain reaction (RT-PCR) capacity to detect influenza A/H5 virus. Daily door-to-door surveillance undertaken in the two affected districts made it unlikely that human cases of influenza A/H5N1 virus infection remained undetected. Two outbreaks of Newcastle Disease were also recorded in Azerbaijan in 2006 (Agayeva & Zeynalova, 2011).

Following the 2006 outbreak of H5N1, the Azerbaijan State Veterinary Control Service (SVCS) initiated active serological monitoring for AI in poultry. Under the SVCS program, blood samples from poultry are tested for the presence of antibodies against H5 by the hemagglutination inhibition (HI) assay using WOAH-standardized reagents. Twelve Zonal Veterinary Laboratories and Regional Veterinary Offices in Azerbaijan are engaged in this surveillance program. Sample collection from domestic birds occurs between September and May each year and testing is performed at the Republican Veterinary Laboratory or its branches. These national laboratories have dedicated Virology Departments. When the Regional Veterinary Offices submit samples for H5 testing, they may also request ND disease testing, which is performed by HI using WOAH-standardized reagents. ND testing is requested for approximately half of the samples submitted (Agayeva & Zeynalova, 2011; Zeynalova et al., 2015).

The Azerbaijan State Veterinary Control Service (SVCS) also conducts the monitoring of migratory birds for detection of avian influenza, which also involves experts of the Ministry of Health and the Ministry of Environment. It covers staging points of migratory birds on their way to national parks and reserves, coastal areas on the Absheron peninsula and the Shabran, Agjabedi, Lankaran and Salyan regions of Azerbaijan. In addition, samples are taken for analysis from poultry and private households. When the pandemic avian influenza was registered in 2006, the Azerbaijan authorities declared a ban on the hunting of birds for many years (Zeynalova et al., 2011).

Iran: In Iran there are a number of scientific institutions and specialists engaged in the detection of pathogens carried by birds. The Department of Environment is very actively involved in this endeavor throughout the country. Perhaps best known internationally, however, is the Razi Vaccine and Serum Research Institute which has branches in various places in the country. It now has a laboratory dedicated to this subject, as well as other departments occupied with related activities. A partial list follows:

- Department of Avian Diseases Research and Diagnostics, Razi Vaccine and Serum Research Institute, Agricultural Research, Education and Extension Organisation (Karaj, Tehran)
- Wildlife Diseases Research Laboratory, Razi Vaccine and Serum Research Institute, Agricultural Research, Education and Extension Organisation (Karaj, Tehran & Shiraz)
- Department of Poultry Diseases, Razi Vaccine and Serum Research Institute, Agricultural Research, Education and Extension Organisation
- Departments of Virology and of Microbiology, Razi Vaccine and Serum Research Institute, Agricultural Research, Education and Extension Organisation (Shiraz).

Islamic Azad University is also involved into research in this field, as are departments of the Faculty of Veterinary Medicine of the University of Tehran:

- Department of Clinical Science, Science and Research Branch, Islamic Azad University (Tehran, Karaj, Alborz & Tehran)
- Department of Microbiology, Fars Science and Research Branch, Islamic Azad University, Fars
- Department of Microbiology, Shiraz Branch, Islamic Azad University, Shiraz
- Departments of Immunology and of Clinical Science, Faculty of Veterinary Medicine, University of Tehran
- Department of Clinical Science, School of Veterinary Medicine, Islam Azad University, Kazeroun Branch.

The Iran Veterinary Organisation has the following specialist facility:

- National Refence Laboratory, Diagnostics and Applied Studies Centre, Iran Veterinary Organisation (Tehran Province).

See also the Iran Veterinary Organisation Avian Influenza Portal: int.ivo.ir/news/Avian-Influenza-Portal.

Kazakhstan: In Kazakhstan avian viruses are monitored and analysed through its extensive government veterinary system within the Ministry of Agriculture under the direction of a Committee of Veterinary Control and Supervision, which is structured as follows:

- A National Veterinary Reference Centre undertakes epizootic monitoring and also provides samples to the WOAH (World Organisation for Animal Health) and FAO UN Food and Agricultural Organization) Reference

Laboratory for Avian Influena and Newcastle Disease in Britain. There is also a Republican Veterinary Laboratory with 16 district regional branches and 188 regional diagnostic branches. 16 are accredited according to ISO/IEC 17025. These undertake sampling and diagnosis of especially dangerous and epizootic animal diseases. A Republican Antiepizootic Detachment undertakes removal and destruction of sick animals. Under Akimat, state eterinary support and management is provided in Nur-Sultan, Almaty and Shimkent and in 197 cities of regional significance, as well as in rural locations throughout the country. Its responsibilities include veterinary measures related to particularly dangerous and epizootic diseases and the maintenance of an animal identification data basis.

The Kazakh Veterinary Scientific Research Institute undertakes fundamental and applied scientific research and provides scientific advisory and practical assistance to economic entities of the Republic of Kazakhstan to ensure veterinary welfare.

There are also two other centres of expertise in this field:

- National Centre for Biotechnology (Nur-Sultan)
- National Laboratory Astana, Nazarbayev University (Nur-Sultan).

Russia: The Federal Service for Veterinary and Phytosanitary Surveillance of the Russian Federation (Rosselkhoznadzor) is the national authority with the responsibility to oversee the monitoring of epizootic diseases nation-wide. Its policy is that public vigilance and close collaboration between the public health, veterinary and environmental authorities together are important to ensure rapid detection of avian influenza viruses in birds and to protect human health. The FGBI "ARRIAH" (hereinafter, the ARRIAH) is involved in control and surveillance activities in veterinary field being subordinated to the Rosselkhoznadzor since 2004. Associated Russian state entities, centres and laboratories are:

- National IHR (International Health Regulations Focal Point)
- Federal Centre for Animal Health (ARRIAH). ARRIAH is involved in control and surveillance activities in the veterinary field being subordinated to Rosselkhoznadzor since 2004
- State Research Centre for Virology and Biotechnology VECTOR (WHO H5 Reference Laboratory), Vladimir
- Laboratory for Epizootology and Monitoring, ARRIAH, Vladimir
- Reference Laboratory for Avian Viral Diseases, ARRIAH, Vladimir.
- The World Organization for Animal Health (WOAH) has granted the Federal Centre for Animal Health (ARRIAH) three international statuses:
  - WOAH Regional Reference Laboratory for FMD (1995)
  - WOAH Collaborating Centre for Diagnosis and Control of Animal Diseases for Eastern Europe, Central Asia and Transcaucasia (1997)
  - WOAH Regional Reference Laboratory for Highly Pathogenic Avian Influenza and Low Pathogenic Avian Influenza (Poultry) and Newcastle Disease (2018).
  - The Food and Agriculture Organization of the United Nations (FAO) has given ARRIAH the status of FAO Reference Centre for Foot-and-Mouth Disease for Central Asia and Western Eurasia to ARRIAH (2013).

ARRIAH has become one of the leading institutions for development and production of veterinary drugs intended for animal disease specific prophylaxis and diagnosis, as well as rendering scientific assistance to veterinarians. It is also actively engaged in training programmess. It has a Dissertation Council for defense of candidate and doctor theses for the Higher Attestation Commission of the Russian Federation, as well as the Department of Education and the Department of Postgraduate Studies. Staff training courses and individual internship programmes are regularly organized.

In February 2021, the National IHR Focal Point for the Russian Federation notified the WHO of detection of avian influenza A(H5N8) in seven human clinical specimens. These are the first reported detection of avian influenza A(H5N8) in humans. Positive clinical specimens were collected from poultry farm workers who participated in a response operation to contain an avian influenza A(H5N8) outbreak detected in a poultry farm in Astrakhan region in the Russian Federation. The laboratory confirmation of specimens was performed by the State Research Centre for Virology and Biotechnology VECTOR (WHO H5 Reference Laboratory) in Vladimir.

In December, a total of 101 000 of 900 000 egg laying hens on the farm died, prompted an investigation. Samples were collected from these birds and an initial detection of avian influenza A(H5N8) was performed by the Russian regional veterinary laboratory. The outbreak was further confirmed by the World Organisation for Animal Health (WOAH) Reference laboratory, and the Federal Centre for Animal Health (ARRIAH), in Vladimir. Outbreak containment operations were instituted.

The human cases remained asymptomatic for the whole follow-up duration of several weeks. Nasopharyngeal swabs were collected during medical observation period and tested negative for avian influenza A(H5N8). No obvious clinical manifestations were reported from any farm workers under medical surveillance, their family members or other close contacts of the seven cases.

The influenza A(H5N8) viruses isolated from the Astrakhan poultry outbreak belonged to clade 2.3.4.4b of avian influenza A(H5Nx) viruses. In 2020, H5N8 viruses were also detected in poultry or wild birds in Bulgaria, the Czech Republic, Egypt, Germany, Hungary, Iraq, Japan, Kazakhstan, the Netherlands, Poland, Romania, the United Kingdom, and the Russian Federation.

Since AI outbreaks were recorded in Crimea in 2005-2008, ARRIAH scientific personnel based both in Simferopol and Crimea have periodically undertaken avian influenza monitoring of wild birds in the wetlands of Crimea and analysed samples in the laboratories of the State Centre for Virology and Biotechnology at Vladimir or locally at:

- Laboratory and Diagnosis Centre, Laboratory for Molecular Diagnostics, Laboratory and Diagnosis Centre, ARRIAH Crimea Branch, Simferopol
- Laboratory for Animal Disease Diagnostics, Laboratory and Diagnosis Centre, ARRIAH Crimea Branch, Simferopol.

See further below: Section 9 "Monitoring avian influenza in Crimea: Dnepr and Azov-Black Sea migratory flyways and connections with Caspian Sea waterbird populations".

Much core scientific field work and analyses of avian influenza and other epizootic diseases is also being undertaken in various research centres, institutes and laboratories of the Siberian Branch of the Russian Academy of Sciences in Novosibirsk, in particular the following:

- Federal Research Centre for Fundamental and Translational Medicine
- Department of Experimental Modeling and Pathogenesis of Infectious Diseases, Federal Research Centre of Fundamental and Translational Medicine
- Genomics Core Facility, Institute of Chemical Biology and Fundamental Medicine
- Laboratory of Behavioral Ecology, Institute of Animal Systematics and Ecology.

The Department of Natural Science at Novosibirsk State University also collaborates with the above organisations, as does the Laboratory of Marine Microbiota, National Scientific Centre of Marine Biology, Vladivostok and the Institute of Ecology and Sustainable Development of Dagestan State University in Makhachkala.

Turkmenistan: In 2021 the GHS (Globally Harmonised System of Classification and Labelling of Chemicals) compiled a detailed Joint External Evaluation (JEE)) of Turkmenistan's capacities in all sectors concerned with the analysis, prevention and response to biological threats (GHS 2021).

Since 2007, as Turkmenistan has important stop-over areas for many thousands of migratory birds which could carry HPAI and other viruses, the World Bank has been supporting the country's efforts to contain and control the spread of avian influenza viruses and to prepare for a possible outbreak affecting people and animals.

Following a thorough assessment of Turkmenistan's laboratory services, the country's central veterinary laboratory was renovated and equipped to allow virus testing in a highly secure and contained environment. 130 staff members were trained to handle and test avian influenza samples safely and accurately. Regional laboratories were also renovated and provided with basic equipment so that staff there could perform preliminary tests. Several Turkmen specialists were also able to attend additional advanced laboratory training programmes of an international calibre.

Key ministries and government agencies practiced responding to a simulated outbreak. As a result, they put in place a number of interagency responses and coordination mechanisms to insure effective collaboration among the Ministry of Health and Medical Industry, the Veterinary Union and Ministry of Agriculture and Nature Protection. An extensive national public communications programe was also undertaken by the Ministry of Health and Medical Industry with input from UNICEF. Nearly three million posters, booklets, brochures, information calendars for each target group—health workers, veterinary workers, schoolchildren, hunters – were printed and disseminated throughout the country.

In 2010, with the support of FAO, the "Anti-Epizootic Action Plan for Counteracting the Pandemic of Highly Pathogenic Avian Influenz" and "Guidelines for Avian Influenza and Information on Swine Influenza for Veterinary Professionals" were developed. These documents are available in Russian and Turkmen.

Consequently, the key responsible Turkmenistan state entities in this sector are currently:

- State Veterinary Service, Ministry of Agriculture and Environmental Protection
- Special Centre for the Control and Prevention of Infectious Diseases, Ministry of Health and Medical Industry of Turkmenistan
- State Sanitary and Epidemiological Services Laboratory (Ashgabat).

Turkmenistan's Ministry of Health and Medical Industry has a Department for Zoology, Parasitology and Animal Care that is responsible for organizing and carrying out collection of materials from the field for analysis in the central laboratory. The Department is now part of the Special Centre for the Control and Prevention of Dangerous Infectious Diseases.

The State Sanitary Epidemiological Service (SSES), also part of the Ministry of Health and Medical Industry, is the National IHR Focal Point for Turkmenistan. Prior to the SSES being tasked to oversee counter measures against outbreaks of zoonotic diseases, that duty was performed by the State Veterinary Department (SVD), which was overseen by the Ministry of Agriculture.

The State Sanitary Epidemiological Service (SSES), maintains regular contact with the WOAH to exchange information on cases of registration of highly contagious infectious diseases in the world

Currently, both the Central and District Veterinary Laboratories have all the necessary diagnostic kits for the detection of Newcastle Disease. The staff of the veterinary laboratory carry out monitoring studies of caught waterfowl. Reports on laboratory tests carried out are sent to the State Veterinary Service. To date, veterinary laboratory specialists have not detected a positive result for AI and ND.

The State Sanitary Epidemiological Service closely cooperates with the WOAH (formerly know as the OIE), USAID, FAO, and the European Union. In 2013, the first OIE PVS mission was carried out to assess the activities of the Veterinary Service of Turkmenistan. The second OIE PVS mission to assess the performance of the Veterinary Service of Turkmenistan took place in November 2017. Every year, its specialists actively participate in training and practical seminars in foreign countries in order to study the latest world achievements and experience in the field of veterinary activities and their implementation in our country

The result has been that the country has had no recorded cases of avian influenza to-date and is now better prepared to respond to any potential outbreaks.

The Training Programs in Epidemiology and Public Health Interventions Network (TEPHINET – the global network of Field Epidemiology Training Programms) provided logistical support for a two-year Field Epidemiological and Laboratory Training Program (FELTP) in Turkmenistan, so that participants could complete FELTP core competencies and successfully graduate from the program. FELTPs play a critical role in advancing global health security by building the public health workforce needed for countries to detect and respond to acute public health threats, including outbreaks, natural disasters, and humanitarian crises. The Turkmenistan programme is listed as ongoing with the United States Center for Disease Control and Prevention (CDC) helping to provide funding. According to the JEE, no structured courses in applied epidemiology equivalent to the short-term FELTP were offered in Turkmenistan itself as part of educational

training, though the Turkmen State Medical University did include some elements of FELTP in a specialized education programme. The JEE said that the university's Preventative Medicine and Epidemiology program incorporates core concepts of field epidemiology and can be generally considered equivalent to the full FELTP course.

In 2018 the Ministry of Agriculture and Environmental Protection of Turkmenistan initiated the preparation of a new published version of the National Strategy of Turkmenistan on Climate Change, with the assistance of the UNDP. This document serves as the main instrument of Turkmenistan reflecting the standpoint of the country during the negotiations and acts as the fundamental document for the preparation of reports on the implementation of its obligations in the framework of global climate agreements, with particular concern for Turkmenistan's concerns over the state of the Aral Sea.

6. Duck species (Anatidae) recorded in the Caspian Sea region and their IUCN Red Book status with note on gulls and terns in the North Caspian region

The following list identifies the ducks species (Anatidae) recorded in the Caspian Sea region with their scientific names and commonly-recognised names in English and Russian. The map (Fig. 8) from the 2008 core publication on climate change and avian influenza by Gilbert et al. indicates the distribution of Anatidae which breed in a geographical range from Western Europe to Central Eurasia and where they winter. As indicated in maps in the EU commissioned assessment of migratory waterbirds which might carry dangerous avian pathogens to Europe (Delaney et al., 2006) (Figs. 2-4), there is a particularly high number of species of Anatidae which winter in central and south Caspian wetlands, when conversely they may transmit to these highly concentrated bird population viruses from the extensive territories in Europe and Eurasia which they frequent in summer.

Oxyura leucocephala	White-headed Duck	Савка	EN
Marmaronetta angustirostris	Marbled Teal	Мраморный чирок	VU
Aythya ferina	Common Pochard	Красноголовый нырок	LC
Aythya nyroca	Ferruginous Duck	Белоглазый нырок	NT
Aythya fuligula	Tufted Duck	Хохлатая чернеть	LC
Anas crecca	Common Teal	Чирок-свистунок	LC
Tadorna ferruginea	Ruddy Shelduck	Огарь	LC
Tadorna tadorna	Common Shelduck	Пеганка	LC
Anas platyrhyncos	Mallard	Кряква	LC
Anas/Mareca penelope	Eurasian Wigeon	Свиязь	LC
Anas/Mareca strepera	Gadwall	Серая утка	LC
Anas acuta	Northern Pintail	Шилухвость	LC
Anas/Spatula querquedula	Garganey	Чирок тресунок	LC
Anas/Spatula clypeata	Northern Shoveler	Широконоска	LC
Clangula hyemalis	Long-tailed Duck	Морянка	VU
Melanitta nigra	Common Scoter	Синьга	LC
Melanitta fusca	Velvet Scoter	Турпан	EN
Netta rufina	Red-crested Pochard	Красноносый	LC
Sibirionetta formosa	Baikal Teal	Чирок-клоктун	LC
Mareca falcata	Falcated Duck	Костатка	NT
Aythya marila	Greater Scaup	Морская чернеть	LC
Bucephala clangula	Common Goldeneye	Обыкновенный гоголь	LC
Mergellus albellus	Smew	Луток	LC

As noted above, certain gulls and terns have also been identified as AI viral vectors. In 2022 a considerable number of ill and dead Caspian Terns (*Hydroprogne caspia*) and a lesser number of Black-Headed Gulls (*Larus ridibundus*) which were apparently suffering from avian influenza were recorded on Maliy Zhemchuzniy Island (historically known as Seal Island) in the Russian north-east waters of the Caspian Sea. The island is protected as an Astrakkhan State Natural Biosphere Reserve and is the only location where Black-Headed Gulls are documented as nesting in the Caspian region. Considerable research was undertaken in the late Soviet period on documenting the gulls and terns frequenting this island and identifying viruses they carried (Andreev et al., 1980; Aristova et al., 1982, 1986). The virus affecting island birds in 2022 is currently being investigated by the Federal Research Centre for Fundamental and Translational Medicine of the Siberian Brach of the Russian Academy of Sciences in Novosibirsk. Caspian Seals also frequent this location, which may have been a source of the infection of the approximately 2,500 Caspian Seals which died in the Caspian Sea in November 2022. In this context, it is worth noting that in the summer of 2022 there were elevated Grey and Harbour Seal mortalities along the coast of Maine in the USA, the cause of which was determined as Highly Pathenogenic Avian Influenza H5N1 by the National Veterinary Services Laboratories of the U.S. Department of Agriculture's Animal and Plant Health Inspection Service.

7. Effects of infected ducks on a unique traditional economy in the south Caspian Sea region

In the southern Caspian coastal areas of Iran, there is an unusual pathway of transmission of harmful viruses of avian origin which has affected local traditional subsistence livelihoods since the avian influenza H5N1 outbreak of 2006. As noted above, in the past, following the harvesting of the annual rice crop, the enclosed rice fields or damgah were flooded and became an attractive haven for migratory ducks which were netted and sold. The ducks were not only eaten by the trappers and their families but

sold as a source of income in in the live poultry markets of local bazaars. This practice was officially curtailed following the 2006 avian influenza outbreak, causing significant consequences to local customary agricultural practices in this region. There was such pressure on the income of local damgah owners that they started to resort to planting a second rice crop in the damgah fields, whose earthen embankments were no longer maintained (Vuosalo-Tavakoli et al., 2008). This led to a debate between the local trappers and the Department of the Environment. During the summer of 2007, agreement was reached and the trappers again started to inundate their lands and prepare their damgah to attract waterfowl in winter. The basis of the agreement was that their birdcatching methods are ecologically more sound than the alternatives (such as shooting), and thus an NGO (the Mazandaran Crane Conservation Association) and the Department of the Environment undertook to compensate them for their losses (Mansouri, 2009).

Figure 8. Satellite image of Caspian Sea region with locations of principal protected littoral wetland reserves frequented by residential and/or migratory waterbirds (Anseriformes and Charadriiformes) indicated by numbers: (1) Astrakhansky Reserve (Volga River Delta); (2) Agrakhansky Reserve; (3) Kislyar Bay Reserve; (4) Lake Adji-Pappas; (5) Gyzylagach Reserve; (6) Anzali wetlands; (7) Miankaleh Reserve; (8) Khazar Reserve; (9) Karagiye-Karakol Reserve; (10) Ural River Delta Reserve. Note: the numbers only indicate the approximate centre of each wetland. For further information on the official protective designation and territory of each protected reserve, see relevant RAMSAR, UNESCO Biosphere, Birdlife International and state online resources

Another example of damgah are those constituting the wetland of Fereidoun-Kenar further east on the southern Caspian coastal plain. The wetland is basically artificial, but serves as an exceptional winter habitat for migratory waterbirds, the trappers obtaining sufficient income each year from this long-established and ecologically sustainable custom (Nourani et al., 2015).

8. Monitoring avian influenza in Crimea: Dnepr and Azov-Black Sea migratory flyways and connections with Caspian Sea waterbird populations

Two important migratory flyways cross the Crimean Peninsula, the Dnepr flyway (geese and ducks) and the Azov-Black Sea flyway (geese, ducks, sandpipers, swans and rooks). An in-depth investigation into the dynamics of the outbreaks of the H5N1 virus in the Azov Sea-Crimea-Black Sea regions was undertaken in the course of the study "Urgent preliminary assessment of ornithological data relevant to the spread of Avian Influenza in Europe" which the European Commission commissioned Wetlands International and EURING (European Union for Bird Ringing) to undertake (Delany et al., 2006).

There are also well-documented connections between the Caspian Sea and the northern and western Black Sea littoral with waterbirds moving from the former to the latter in reaction to cold weather. There is also an exchange of waterbirds between the Sivash lagoon behind the narrow Arabat Spit along the western Asov Sea and the Black Sea wetlands (Fig. 9). In winter, during severe weather conditions, parts of the Eastern Sivash with low salinity may freeze up and then waterbird concentrations move to open hypersaline water areas in the southern part of the Eastern and Central Sivash. In the extremely severe winter of 2006 all Sivash waters became frozen and all wintering waterbirds concentrated along the southernmost coast of the Crimean peninsula, some moving to the western wetlands of the Black Sea where they may have contributed to the outbreak of the H5N1 virus in these areas (Delaney et al., 2006).

Here it should be noted that according to EURING's Data Bank, at least two species of duck, the Northern Shoveller (*Anas clyreata*) (Fig. 10) and the Red-crested Pochard (*Netta rufina*), as well as the Black Tern (*Chlidonas niger*) have migratory routes between the wetlands of the north-west Caspian Sea and the Crimean peninsula (Fig. 11) (Bauer et al., 2006).

Villages throughout the Eastern Sivash commonly keep free roaming chickens, ducks, geese and turkeys. Domestic geese and ducks visit ponds, canals and artesian-fed reservoirs in the vicinity of villages. As the number of these sources of fresh water is limited, birds from different households congregate in such places which are also frequented by wild birds. To combat the risk of transmission of pathogens state veterinarians instruct local people to keep their poultry (and domestic dogs and cats as well) within their yards (Delany et al., 2006).

As along the coasts and islands of the Caspian Sea, gulls and terns may play a linking role in the spread of disease carrying the virus from the habitats of concentrations of wild waterbirds to various water bodies frequented by domestic birdsgull. In August, when their numbers reach a maximum, many gulls and terns forage over agricultural fields and come close to settlements, roosting on ponds in or near villages (Delany et al., 2006)

A series of outbreaks of H5N1 occurred in the Eastern Sivash in the winter of 2005-2006. The first outbreak was recorded in October in the village of Nekrasovka which is located next to one of the most important waterbird concentration areas in the Sivash. Many of waterbirds (especially Greater White-fronted Geese (*Anser albifrons*) and Mallards (*Anas platyrynchos*)) forage on agricultural fields near villages where they mingle with domestic ducks and geese. A second outbreak occurred in November 2005, shortly after a cold spell had brought thousands of waterbirds to the area, among which were some 15,000 Greater White-fronted Geese. A third outbreak took place in mid-January 2006. At that time the Volga delta had become totally frozen, resulting in large numbers of waterbirds leaving the Caspian Sea area, visiting the Eastern Sivash, after which they were forced further westwards by freezing conditions. In all cases the onset of outbreaks could be related to the existence of waterbird concentrations or major migratory movements of these birds (Delany et al., 2006).

From March 2006 through November 2008, 20 AI viruses were isolated in the peninsula with an overall frequency of virus recovery of 3.3%. All viruses isolated were from three species of dabbling ducks: mallard (*Anas platyrhynchos*), wigeon (*Anas penelope*), and garganey (*Anas querquedula*), making the frequency of virus recovery for dabbling ducks 6.3%. The viruses were mainly isolated during the fall sampling period (Kulak et al., 2010; Vorotilova et al., 2015). 62% of cases were reported in the Eastern Sivash lagoon behind the narrow Arabat Spit (whose previously saline waters had been flooded with fresh water from the North-Crimean Canal from Ukraine since 1963), 23% in the Black Sea littoral of the Feodosia municipality and the Chernomorsky and Krasnoperekopsky districts and 15% in Central Crimea (Simferipolsky, Belogorsky and Krasnogvardeisky districts). In total some 265,110 birds (poultry and wild) were estimated to have died from HPAI in Crimea from 2005-2008 (Gadzevich et al., 2018).

In 2018, further monitoring of avian influenza on aquatic and semi-aquatic birds in the Azov Sea and Sivash wetlands area was undertaken by specialists of the Federal Centre for Animal Health (ARRIAH) branch and laboratory in Simferopol, Crimea, in collaboration with ARRIAH in Vladimir, Rosselkhoznadzor and onithologists. During their expeditions biological material samples were collected, bird species identified and bird fauna estimated in waterfowl aggregation sites (Kuchuk-Ajigol, Sasyk-Sivash, Donuzlav lakes and Sivash lagoon) (Gadzevich et al., 2018).

Testing of samples was undertaken by the Central Research Institute of Epidemiology of the Federal Service for Customer Rights Protection and Human Well-being in Vladimir. Laboratory PCR tests of the biological material collected in the wild as well from killed birds and poultry revealed no AIV type A. As the number of waterbirds in their post-1963 aggregation in the Sivash wetlands had decreased due to the fact that fresh water supply through the North-Crimean Canal has ceased since 2014, it was considered that the Crimean Peninsula would manage to maintain HPAI freedom despite the fact that the disease was reported close to the peninsula. In the winter of 2018-2019 there was indeed recorded a significant decrease in the number of wintering of birds (Common Pochards, *Aythya ferina*, for example, had not wintered in Crimea the previous two years, possibly due to the absence of feed). Nevertheless, notwithstanding the fact that since 2009 no

HPAI cases or related deaths among poultry had been reported in the Crimean peninsula, ARRIAH advised that the threat of virus introduction to commercial and backyard farm stocks still existed as the peninsula is located on bird migration routes and that AI epidemiological monitoring must continue to be undertaken, because the risk of virus introduction was still high (Gadzevich et al., 2018).

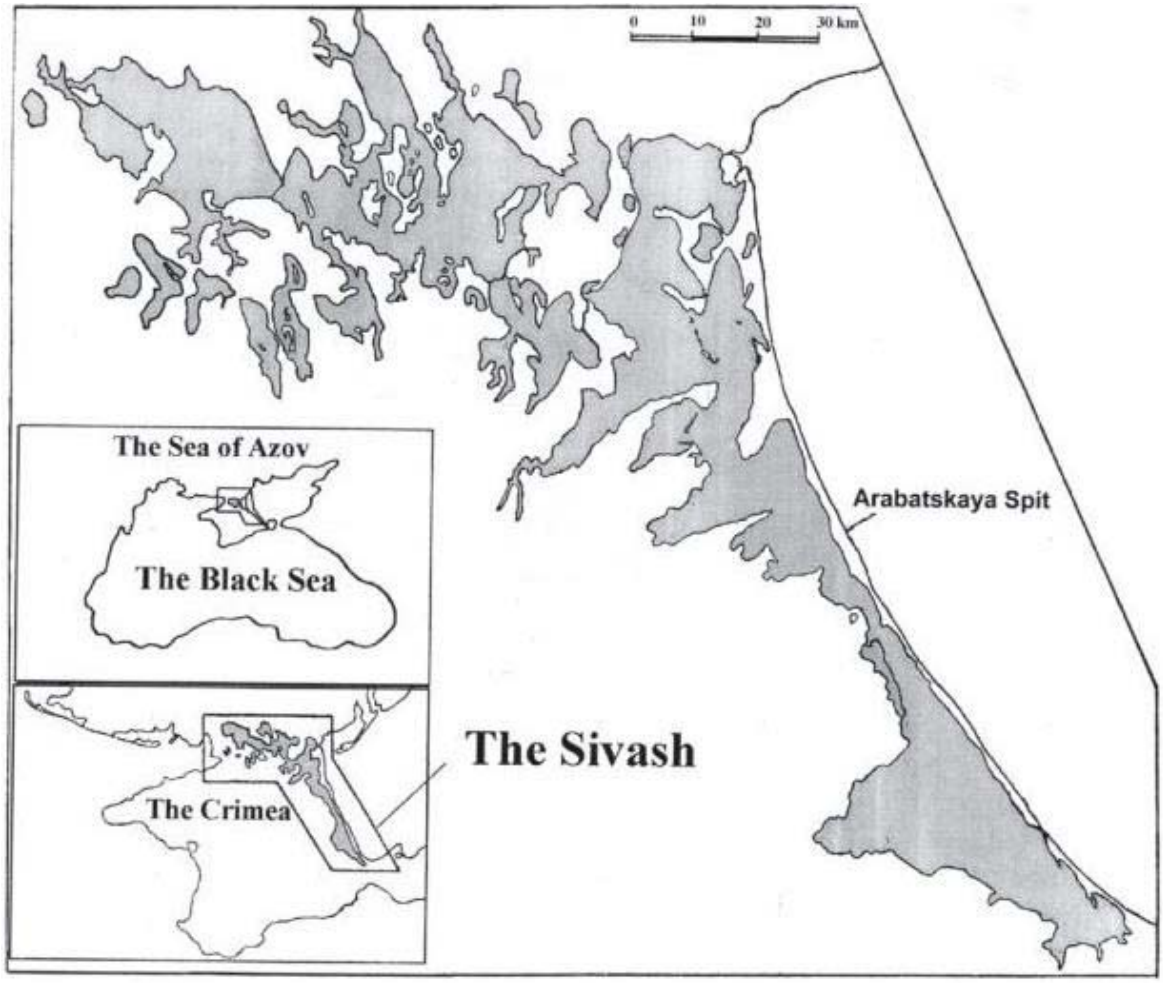

Figure 9. Map of the Crimean Peninsula with the location of the Sivash lagoon system behind the Arabat spit (after Khomenko, 2006)

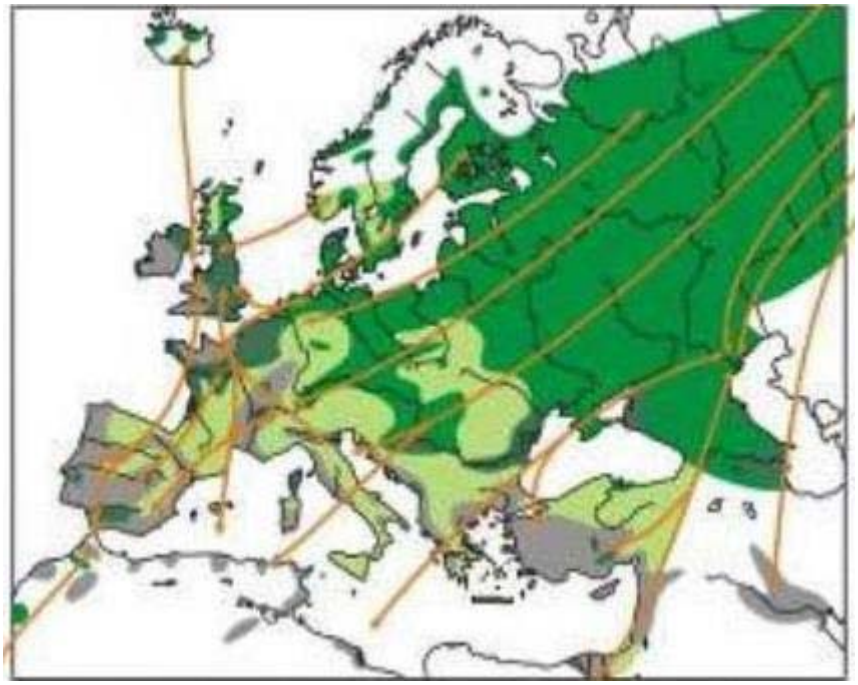

Figure 10. Northern Shoveller (*Anas clyreata*) wintering migration map (after Bauer et al., 2006; Aula Verlag)

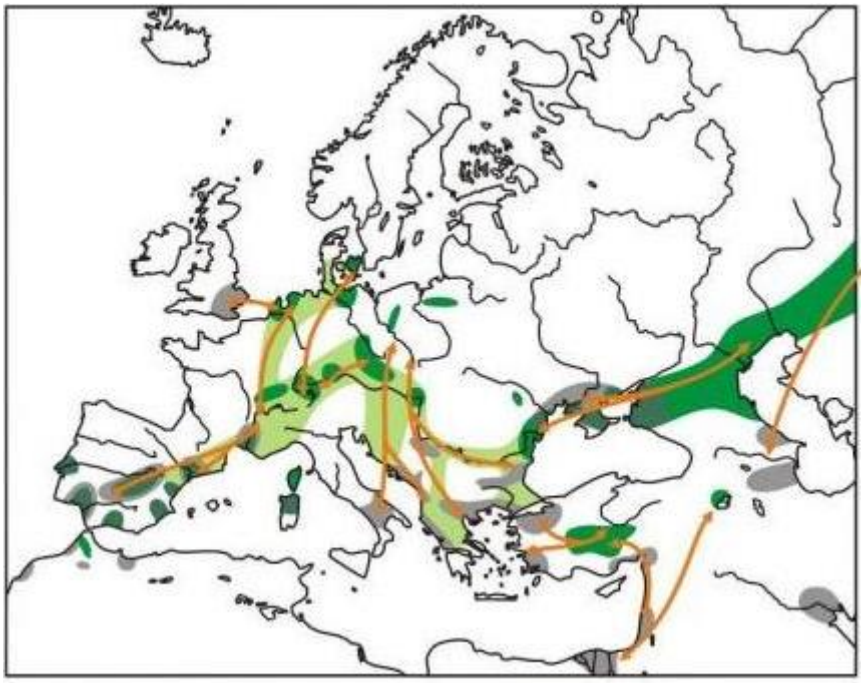

Figure 11. Red-crested Pochard (*Netta rufina*) wintering migration map (after Bauer et al., 2006; Aula Verlag)

This cautious stance was justified after epidemiological monitoring in 2019 and 2020 by Gadevich et al. of the Federal Centre for Animal Health (ARRIAH) in Simferopol and Vladimir was again undertaken in the territory of Crimea (Gadzevich et al., 2019). Their attention was focused on the study of water basins of the Azov and Black Seas, the Sivash Lagoon and freshwater lakes in the Feodosia Municipality, Leninsky, Sovetsky, Nizhnegorsky, Chernomorsky and Saksky districts. Examination of these areas showed that some freshwater reservoirs had become shallow and dry and that aquatic vegetation had degraded. A natural biotope analysis conducted in 2019 and 2020 showed a decrease in the number of semiaquatic wild birds. Pathological material was sampled from semiaquatic and migratory wild birds, as well as from poultry kept in poultry farms and backyards. The collected samples were tested using real-time RT-PCR. In 2019, the AIV type A (H9) genome was detected in one fecal sample taken from wild birds near Kuchuk-Adzhigol Lake in the Feodosia Municipality. The AIV type A (H5) genome was detected in 2020 during laboratory testing of pathological material taken from the remains of a mute swan within the shoreline of a freshwater lake near the Ermakovo settlement of the Dzhankoysky district. The genetic analysis was performed in the ARRIAH laboratory at Vladimir, where the N8 subtype neuraminidase of the influenza virus isolate was identified. The comparative genetic analysis of 258 bp nucleic acid sequences of the AIV H gene fragment showed that the identified isolate belongs to the Asian genetic lineage of highly pathogenic AIV subtype H5 (clade 2.3.4.4) associated with the epidemic spread in Asia, Europe, the Middle East and Africa in 2016–2020 (Gadzevich et al., 2021).

9. Documentation of effects of climate change on birds frequenting the Caspian Sea

As it is conceived, the ViEW system could contribute significantly over a period of time to the detailed systematic documentation and analysis not only of avian-borne pathogens but also of the impacts of climate change on both migratory and resident waterbird species of the Caspian region. While a large amount of meteorological and ecological data have already accumulated in this regard, much is either subjective or anecdotal in character or refers to proxy information from international scientic sources. While scientists and conservationists benefit greatly from the information, methodologies and prognoses of research undertaken outside the region, it cannot fully substitute for the properly targeted and quantified observations and compilations of specialists of the Caspian states themselves. This work must be undertaken on an integrated long-term basis rather than through competent but short-term “expeditions”, as has been the legacy of Soviet practice in most scientific fieldwork in Russia. There should be maximum use of new research technologies developed and employed internationally, e.g. radio-tracking, analysis of isotope ratios in bird feathers, whole-genome sequencing, identification of genomic markers (single nucleotide polymorphisms), radionucleides to determine populations and movements, etc.

Migration and overwintering greatly contributes to shaping bird population dynamics. Long distance flights and winter habitat quality may have carry-over effects on subsequent breeding success. Climate change has direct and indirect effects on birds and migratory species are particularly sensitive. Notably, altered climatic conditions can modify migration phenologies and result in shifting wintering and/or breeding areas, with consequences for migratory distances. (Clairbaux et al., 2019). Of particular interest is the possible emergence or re-remergence of pathogenic viruses held in the deep laters or organic matter in the permafrost of Arctic northern Eurasia whose upper layers are increasingly melting with warmer overall ambient temperatures (some 70% of the land area of the Russian Federation is now in this category). There is a concern that these pathogens could theoretically be transmitted to waterbird species breeding in the regions underlaid with permafrost and passed on further geographically through migration. A tangible testimony to

the ancient intimate connection between now extinct mammals, migratory waterfowl and humans in the high Arctic, relics of which are now emerging from the melting permafrost, are the Late Palaeolithic (^{14}C dated to c. 15,000 yrs BP) pendants of flying Anatidae carved from mammoth tusks; excavated by archaeologist M.M. Gerasimov in Malta northwest of Lake Baikal in Siberia in 1928-1930 (Abramova, 1995; Derevianko et al., 1998) (Fig. 12).

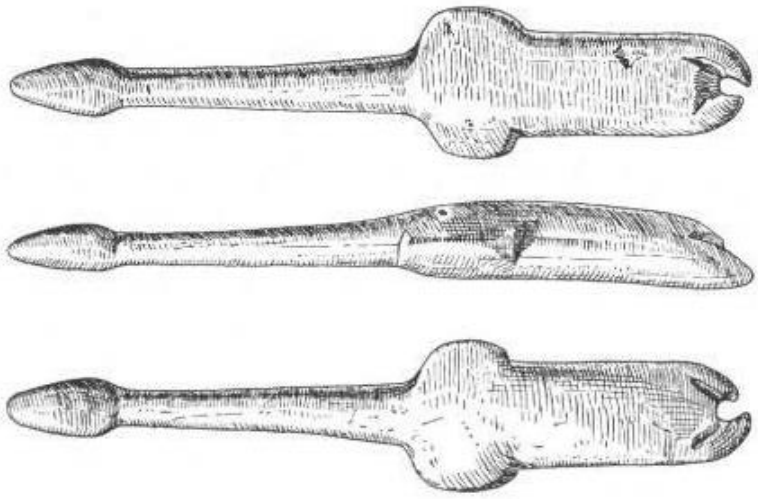

Figure 12. Carved mammoth tusk pendants of high flying waterfowl. Radiocarbon dated to c. 15,000 BC (Late Palaeolithic. Malta-Buret mammoth-hunting culture). Excavated in burial sites in Malta, Usolsky district on a branch of Angara River in central southern Siberia, north-west of Lake Baikal (the most ancient known site in region). Four such pendants were found in situ deliberately orientated north-south according to bird migration pattern and still-held traditional local beliefs in the path of the soul after death. State Hermitage Museum, Saint Petersburg (after Abramova, 1995)

Despite the deficit of detailed data on climate impacts on birds, specialists in the Caspian region have observed and documented on a macro level the indubitable reality and effects of warming trends on the environment. For instance in Turkmenistan during the mid-winter of 2021-2022 a state ornithological expedition surveyed the birds and environmental status of most of the Khazar Nature State Reserve littoral. The ornithologists involved reported that that the coastline and water surface areas of the bays had undergone strong transformation due to a decrease in sea level caused by a number of factors including global warming. On the northern coasts, where rock uplands prevail, most of the lagoons, bays and gulfs, which used to be abundantly inhabited by birds, had dried up. Thus the biocapacity of the natural locations investigated has resulted in a significant decrease in the number of birds wintering in Turkmenistan. On the lower central and southern coasts the shorelines have shifted by kilometres, which has negatively affected bird observation possibilities. A number of bird clusters could only be assessed by the ornithological team in approximate quantitative terms.

A very revealing study by an Iranian group of researchers, Alemi Safaval et al., was published in 2018 of recent, ongoing and possible drastic future consequences of Caspian sea level changes and their effects on coastal morphologies. These may have a major ecological impact on the phenologies of migratory waterfowl and patterns of potential pathogen transmissions.

10. CONCLUSIONS

As did many other specialists before the outbreak of the global COVID-19 pandemic of epizootic origin, Aaron Bernstein, Director of the Center for Climate, Health, and the Global Environment at Harvard University's T.H. Chan School of Public Health, warned that, "*The destruction of natural places drives wild life close to people and climate change is also forcing animals to move. That creates an opportunity for pathogens to get into new hosts. The separation of health and environment policy is a dangerous illusion. Our health entirely depends on the climate and the other organisms we share the planet with.*"- a warning echoed by Lycett S.J. et al. (2019) "*The threat of a new avian influenza virus causing a human pandemic is still present today... Therefore, if we continue the disease surveillance programmes in avian, human and other domestic animal populations, and control avian influenza in domestic avian populations, then we can surely reduce the risks of a new human avian influenza pandemic*".

The review of activities and opinions of specialists and organizations with remits relating to the development, establishment and maintenance of such a system as is conceived for ViEW, clearly indicates that a research, surveillance and early warning system for AIV in the Caspian Sea region is a priority necessity for global animal and human health due to the role the region plays through the mass migration of species of waterbird already known as vectors for avian influenza and the already evident and concerning – but as yet not adequately understood or quantified - impacts of climate change on their phenologies. The waterbirds congregating in massive numbers in their habitats along the coasts and hinterland wetlands of the Caspian Sea make the territory a potential

global hotspot for highly pathogenic avian influenza outbreaks and a source of rapid transmission of these diseases geographically.

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AUTHOR CONTRIBUTIONS

Guy Petherbridge co-developed the concept, undertook the literature review, analysed the information gathered from the literature and scientific partners and wrote the article. Alimurad A. Gadzhiev co-developed the concept, contributed to the literature review and guided the research. Alexander M. Shestopalov contributed research data, contributed to the literature review and guided the research. Alexander Yu. Alekseev guided the literature review and contributed research data. Kirill A. Sharshov contributed to the literature review, and provided research data. Madina G. Daudova was responsible for the editing and formatting of the article. All authors are equally responsible for plagiarism, self-plagiarism and other ethical transgressions.

КРИТЕРИИ АВТОРСТВА

Гай Петербридж был соавтором концепции, провел обзор литературы, проанализировал информацию, полученную из литературы и от научных партнеров, и написал статью. Алимурад А. Гаджиев был соавтором концепции, участвовал в обзоре литературы и руководил исследованием. Александр М. Шестопалов предоставил данные исследования, участвовал в обзоре литературы и руководил исследованием. Александр Ю. Алексеев руководил обзором литературы и предоставил данные исследования. Кирилл А. Шаршов участвовал в обзоре литературы и предоставил данные исследования. Мадина Г. Даудова рассмотрела исследование и провела редактирование и форматирование статьи. Все авторы в равной степени несут ответственность при обнаружении плагиата, самоплагиата или других неэтических проблем.

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