

Controlling the risk of spill over of peste des petits ruminants virus from livestock to threatened wild ungulates in Wakhan National Park, Afghanistan

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Abstract

Peste des petits ruminants (PPR), is a highly contagious and devastating viral disease of small ruminants. It has been endemic in Afghanistan for more than 20 years. PPR has emerged as a serious animal health concern in Central Asia as it threatens the small-scale sheep and goat farming of millions of low-income families. There is also increasing evidence of spill over of PPR virus (PPRV) from domestic to wild animals with devastating effects on populations of susceptible wild ungulates. The Wakhan National Park (WNP) in Afghanistan was created in 2014 to protect a unique and vulnerable high mountain landscape. It is home to ca. 17,000 people and ca. 60,000 livestock sharing to various extents pastures with vulnerable populations of Marco Polo sheep (*Ovis ammon polii*), Siberian ibex (*Capra sibirica*) and urial (*Ovis orientalis*). Because of this cohabitation, the weak sanitary surveillance, limited access to vaccination, and the reported cross border movements of livestock and wildlife, the populations of wild ungulates in Wakhan are at significant risk of PPR infection. Serosurveillance in sheep and goats carried out in 2006-2011 documented an annual prevalence ranging 1.2% – 7.5%. However, in winter 2012 a disease outbreak that claimed the life of ca. 4,500 sheep and goats with suggestive clinical symptoms supported that PPR could occur as episodic outbreaks followed by periods of clinical ‘silence’. In support of the management of WNP, the Wildlife Conservation Society in partnership with the government and local communities has identified possible areas of PPR spill-over to wild ungulates and most-at-risk species, it has also supported the creation of a surveillance network of local paraveterinarians, it has piloted a transboundary animal health detection effort, and in 2017, vaccinated 8,117 sheep and goats in areas of the park of higher risk of PPR spill over to urial sheep.

The emergence of peste des petits ruminants in Central Asia and the global risk to wildlife

Peste des petits ruminants (PPR), is a highly contagious and devastating viral disease of small ruminants in Africa and Asia. The causative agent is a single negative-stranded RNA virus (PPRV), which belongs to the genus *Morbillivirus* (such as measles virus in humans) of the family *Paramixoviridae*, with four identified lineages; lineage IV dominating in Asia (Parida et al. 2015).

In Asia the virus has been endemic in India, Pakistan and probably Afghanistan for more than 25 years (Parida et al. 2015). Recently it has expanded its range in Asia and reached in 2004 western Turkey, the eastern gateway to Europe (Anderson and Sammin, 2005). In Central Asia it has been confirmed in 2004 in southern Tajikistan (Orynbaev et al. 2005; Kwiatek et al. 2007), then in western China in 2007 (Wang et al., 2009), in southeast Kazakhstan in 2014 (Kock et al. 2015) and in western Mongolia in 2016 (Shatar et al. 2017). PPR has emerged as a serious animal health concern in Central Asia as it threatens the small-scale sheep and goat farming of millions of low-income families.

There is also increasing evidence in Asia of spill over of PPRV from domestic to wild animals with devastating effects on populations of susceptible free-ranging wild ungulates, such as on blue sheep (*Pseudois nayaur*), Siberian ibex (*Capra sibirica*) and argali sheep (*Ovis ammon*) in China (2007-2016) (Bao et al. 2011, Zhu et al. 2016); wild goats (*Capra aegagrus*) and urial sheep (*Ovis orientalis*) in Iraq's Kurdistan (2010-2011) and Iran (2014-2017), respectively (Hoffman et al. 2012; Marashi et al. 2017); and saiga antelope (*Saiga tatarica*), argali sheep, Siberian ibex and goitered gazelle (*Gazella subgutturosa*) in Mongolia (2016-2017) (<http://www.fao.org/news/story/en/item/463932/icode/>).

In captivity many species of Asian ungulates have been confirmed or suspected of being susceptible to the disease, including blue sheep, dorcas gazelle (*Gazella dorcas*), markhor (*Capra falconeri*), mountain gazelle (*Gazella gazella*), Nubian ibex (*Capra nubiana*), rheem gazelle (*Gazella subgutturosa marica*), urial sheep, and wild goat (Munir 2014).

The Wakhan National Park

The area, known as the Wakhan Corridor, is a narrow strip of land 10,950 km² in size, located in the extreme northeast of Afghanistan. It is nearly 300 km in length and 17–63 km wide, lying between Tajikistan to the north, Pakistan to the south, and China in the east (Figure 1). The area embraces the source of the 2,400 km-long Panj-Amu Darya River, one of Central Asia's great rivers. The climate is typical dry continental with cold winters, short, hot summers and limited precipitation. The Wakhan National Park (WNP) was created in 2014 to protect fauna and flora in the entirety of the Wakhan District. The ecology of WNP is determined largely by its high elevation and the very large changes in elevation (approximately 2,512–7,492 m = difference of 4,980 m). The lowest-lying areas

of the Park are along the Panj River up to its confluence with the Pamir River. The highest point is Mount Noshag (7,492 m) located in the extreme southwest corner of the Park. The park hosts a unique and abundant fauna and flora typical of Central Asian highlands. In total, less than 25% of the WNP is vegetated with the most common vegetation classes being *Artemisia* types (11.9%) and Alpine grass and forbs (6.5% of area). Nearly 59% of the Park area is barren ground and over 14% is glacier. WNP represents the core population of snow leopards (*Panthera uncia*) in Afghanistan with an estimated population of ca.140-180 animals (Ostrowski et al. 2016) (Plate 1). Other carnivores include the brown bear (*Ursus arctos*), the gray wolf (*Canis lupus*), the Eurasian lynx (*Lynx lynx*) (Habibi 2003), and several species of mesocarnivores including the near-threatened Altai weasel (*Mustela altaica*) and the common otter (*Lutra lutra*) (Habib 2007, Ostrowski 2016). Three species of large and charismatic mountain ungulates: the Marco Polo sheep (*Ovis ammon polii*), the Siberian ibex (*Capra sibirica*) (Plate 2) and the urial (*Ovis orientalis*), form a unique and rich assemblage of ungulate species in the region. Also, more than 250 species of birds have been recorded in the Wakhan District since 2006 (WCS database).



Plate 1. A snow leopard (*Panthera uncia*) camera trapped in the Karakoram Mountain Range of Wakhan National Park, summer 2017. Credit: @WCS Afghanistan



Plate 2. A group of male Siberian ibex (*Capra sibirica*) in the Hindu Kush Mountain Range of Wakhan National Park. Credit: @Naqib Mostafawi /WCS Afghanistan

Two ethnic communities totaling about 17,000 people occupy WNP (Callahan 2013; Ostrowski and Rajabi 2017a); the Wakhi and the Kyrgyz (Shahrani 2002). The Kyrgyz are strict pastoralists and live year round in the Little Pamir and eastern Big Pamir at extreme elevations ranging 3,900 m – 4,500 m while the Wakhi have permanent villages in the Wakhan Valley (2,500-3,100 m asl) with summer camps traditionally in the Western Big Pamir and Hindu Kush. In recent years, the Wakhi have been expanding their summer grazing into western Little Pamir areas abandoned by the Kyrgyz. Wakhi are agropastoralists farming the bottomlands of the Wakhan Valley and lower areas of the Pamirs while grazing higher elevations in the Hindu Kush, Big and Little Pamirs between May and October. Wakhi have only recently begun winter grazing in the Pamirs.

Livestock in the Wakhan National Park

Livestock is the critical factor affecting many aspects of WNP. Livestock provides the backbone of the local economy, governs human distribution on the land, limits plant biomass and diversity, and therefore affects ecosystem function. Livestock compete with wild ungulates for food and space and potentially spread disease to both wild animals and to humans. Finally livestock predation by wild carnivores occasionally invokes retaliatory killing.

Based on estimates made by Callaghan (2013) and Ostrowski and Rajabi (2017b) and those collected in 2014 by WCS veterinary team for the Wakhan Valley (WCS, unpublished data), WNP currently harbors about 60,000 livestock including 45,000 sheep and goats, 6,500 cattle, 5,000 yaks, 2,500 donkeys, 1,000 horses and 180 camels. This is a significant increase compared to the FAO livestock counts carried out in 2002-2003, which estimated 14,127 sheep and goats, 5,146 cattle, 991 donkeys, 291 horses and 115 camels in the Wakhan District (FAO 2008). This increase might in part be a reflection of tendency towards underestimation in the FAO questionnaire survey.

The status of peste des petits ruminants in livestock in Wakhan

Animals infected with PPRV transmit the virus to close in-contact susceptible animals through exhaled aerosol or natural excretions (lacrima, nasal, saliva, feces) (Parida et al. 2015). As most RNA viruses PPRV is temperature sensitive and readily inactivated in a dry environment. In Wakhan the virus is therefore unlikely to survive for long time in the external environment. Clinical signs of PPR infection in livestock are similar to rinderpest in cattle (the two organisms are closely related) and may include fever, necrotic stomatitis, gastroenteritis, and bronchopneumonia. The morbidity and mortality rates can be up to 100% in severe outbreaks. In milder outbreaks, morbidity is still high but the mortality rate may be closer to 50%. Severity depends upon the susceptibility of the population. Goats are generally more susceptible to PPR than sheep.

We tested serologically healthy non-vaccinated sheep and goats sampled throughout the Wakhan Valley in July 2007, July 2010, and September-October 2011. We found prevalence values of 7.5% (CI95% 5.3%-10.3%), 1.2% (CI95% 0.4%-3.5%), and 1.4% (CI95% 0.5%-4.1%), respectively. In early spring 2012 Wakhi herders reported of a disease outbreak that claimed the life of ca. 4,500 sheep and goats wintering in the Wakhan Valley. Although animal health experts could not reach the area to investigate the outbreak, the symptoms described by herders that included pyrexia (fever), and a combination of bronchopneumonia and hemorrhagic diarrhea associated with high mortality especially in goats were suggestive of a PPR outbreak. In addition the sheep and goat population tested serologically in September-October 2011 was re-tested in October 2012 (6-7 month after the outbreak) and presented a significant increase of PPRV prevalence at 20.7% (CI95% 16.5%-25.6%). The symptomatology and the significantly higher prevalence in 2012 supported that the spring outbreak was due to a PPR virus. The epidemiology of the disease in livestock in Wakhan is still poorly known but seems to occur as epidemic bursts in sheep and goats followed by periods of silence. Because there is no known carrier state (i.e. the infectious agent surviving in a species without affecting it) (Parida et al. 2015), and cattle do not excrete the virus in case of subclinical infection. In absence of specific studies, it is hypothesized, such as the cattle, that the domestic yak is not capable of excreting the

virus, and thus is not considered to be an important species in the epidemiology of the virus in Wakhan.

Assessing the risk posed by peste des petits ruminants to wild ungulates in Wakhan

In Afghanistan the limited veterinary services and vaccination efforts during the last four decades combined with the effect of drought, overgrazing and civil strife have resulted in widespread occurrence of livestock diseases. Because of its remoteness, Wakhan has suffered until 2008 of no animal health support and anecdotal vaccination efforts.

In a questionnaire survey carried out in 2009 in 32 of the 44 villages of the Wakhan Valley, 120/150 (80%) herders interviewed stated that the disease, featured to them as the association of “fever + diarrhea + cough + high proportion of death + higher susceptibility of goats”, was of relatively recent occurrence in Wakhan and possibly appeared in the area only ca.15 years ago during civil war times. Twenty-eight herders said that the disease occurred in the area for ‘very long time’ and two respondents had no opinion on this matter. When asked about the suspected recent origin of the disease, 56 (46.7%) of the 120 herders believing in the recent emergence of the disease said that they did not know the origin of it, 29 (24.2%) that the disease appeared in Wakhi livestock between 1992 and 1995 when large herds of small ruminants originating from north-east Afghanistan used the Wakhan corridor to reach livestock markets of northern Pakistan. Kabul, the secular marketing outlet for these livestock herds, was no longer accessible, due to interethnic wars of succession. Contaminated herds moving through the corridor arguably disseminated the disease among Wakhi livestock. From a historical point of view, this hypothetical story was believable since Wakhan and Pamirs were renowned for centuries as livestock production areas where non-native domestic animals were seldom introduced (Dr Farman Ali, AKDN, pers. comm.). Then 28 herders (23.3%) said that the disease came from Badakhshan via Afghan traders (essentially from Badakhshan and Panshir) who are bringing their animals almost every summer to be fattened in Pamirs by Wakhi and Kyrgyz, and 6 (5%) that it came either from Kyrgyz livestock in Little Pamir or from ‘upper Wakhan’. Whatever is the origin of the disease in Wakhan, it seems that the Wakhan Valley, which is the most accessible route for livestock movements in the area, played the role of an axis of propagation of PPR in the area.

In 2007- 2009 we studied the possibility of transmission of infectious agents from livestock to Marco Polo sheep (=argali) through direct contact. The effectiveness of a direct contact depends on the brief survival of the infectious agent in the environment, particularly in aerosols, and on the distance between the ‘source’ and the ‘receptor’ individuals. Laboratory studies have shown that pathogens with an enhanced ability to survive outside hosting cells and tissues (existence of an envelope or other protective structures) may be more resilient in the environment and probably more infective than those fragile outside their cellular environment, such as PPRV. The effectiveness of infectious aerosol according

to the distance between the source and the target has been rarely studied. Dixon et al. (2002) showed that strains of *Mannheimia haemolytica* (formerly known as *Pasteurella haemolytica*) nebulized into a wind tunnel can remain viable over a distance of ~20 m. However this estimate applies to an infectious agent that is known to poorly survive in aerosols (Gilmour et al. 1990). In addition the measurements were carried out in a horizontal setting, and distance effectiveness of such aerosol may prove even greater in mountain areas with significant vertical distances. In our study we assumed conservatively that a direct contact could occur when the simultaneous locations of a wild individual and a domestic were within a 100-m horizontal distance.

Using the data retrieved from GPS collars fixed on livestock and from GPS hand held units used three times a day by trained shepherds, we showed that in summer in Big Pamir only marginal contact zones exists between tended groups of sheep and goats and argali (Figure 2). Also between 2006 and 2008 we interviewed shepherds and elders of 75 Wakhi households pasturing their livestock in Big Pamir during summer. We asked them about the occurrence of direct contacts between their herds of sheep and goats and argali (i.e. observations of a Marco Polo sheep and a domestic animal within a 100-m horizontal distance). None of the respondents had made such observations. Marco Polo sheep in Pamirs are shy of men and dogs and do not approach tended herds closer than several hundred meters. Such avoidance behavior is probably linked to a significant level of persecution. These results were also confirmed by observations made by field biologists studying argali in Big Pamir during the same period of time (e.g. Harris et al. 2010). None of us ever observed close contact between Marco Polo sheep and tended herds of sheep and goats. During winter however argali are known to shift their range use to areas of lower altitudes where winter vegetation is still accessible. Herders overwintering groups of sheep and goats in the study site, mentioned that argali sometimes come close to their tended groups of sheep and goats, yet not less than 100 m. They also mentioned that during very harsh winters weakened or debilitated argali may occasionally come in the vicinity of settlements but in such circumstances we believe that shepherds or their dogs would inevitably kill (and eat) them. Direct contacts between livestock and argali do however occur in the case of free-ranging domestic yak. Both Drs. John Winnie and Rich Harris (pers. comm. in 2007) have observed free-ranging groups of domestic yak in relatively close contact with argali in Pamirs. We made similar observations in October 2007 in Big Pamir grazing areas where we saw on one occasion argali and domestic yak grazing in a mixed group. Kyrgyz have reported similar observations in Little Pamir (Salahudin Isamili, WCS, per comm. 2015). Both species seem to tolerate each other very well. Although GPS study of range use by yak herds did not demonstrate an obvious sharing of their 'home ranges' with argali, we only monitored the movements of 5 out of an estimated 25 groups of yaks summering in Big Pamir. In view of the large range use of one of the monitored groups (LoCOH algorithm; ~362 km²), and the ability of yak to access the roughest terrains at

altitudes sometimes exceeding 5,000 m, there is no doubt that yak may overlap to some extent with argali in Big Pamir.

The important finding arising from this study was that argali in Big Pamir avoid direct contacts with tended herds of sheep and goats but do intermingle occasionally with groups of domestic yak. Furthermore because 1/the probability of transmission of PPRV through indirect contact (e.g. soil contaminated with excrete from a sick animal) is low, 2/argali and sheep and goats usually do not share same water resources and 3/yak are not known to excrete the virus, we concluded that argali in Afghan Pamirs were not at immediate risk of being infected by PPRV transmitted by infected sheep and goats.

In April and May 2011 five teams from the WCS project in Wakhan associated with local rangers conducted a longitudinal west-to-east survey of urial sheep and Siberian ibex in the southern slopes of the Hindu Kush mountain range of the Wakhan District, between Fitr village at the entrance of the Wakhan corridor, and Sarhad-e Broghil village where the car track ends. The WCS veterinary team participated in this large-scale survey. In addition to documenting numbers and distribution of ibex and urial, the veterinary team used the opportunity of this longitudinal large-scale investigation to record the concomitant presence of livestock and wild ungulates in surveyed habitats. Siberian ibex were present in 11 out of the 16 surveyed areas and urial in only five of these areas. Ibex were never observed at close distance from a herd of sheep and goat, but one group of urial was observed at less than 150 m from a group of sheep and goats in one location. This observation has been supported by results of interviews of nine local herders who all mentioned that groups of urial often intermingle with cattle and yak and can occasionally come at less than 100 m from a group of tended sheep and goats in absence of dogs. According to them ibex could also share a relative proximity with sheep and goats in this part of Wakhan although the habitat used by ibex and urial differ markedly. While ibex use in general steep rocky habitat, less accessible to livestock, urial prefer 'softer' hilly landscapes and are often observed in rolling hills surrounding relatively flat areas favored by livestock. This habitat preference renders urial potentially more exposed to direct contacts with livestock and their pathogens than ibex. Furthermore urial in Wakhan have been observed to intermingle with cattle (Plate 3) and to use river sources to drink, sometimes downstream a livestock herd.

The conclusion of these investigations was that in Pamirs argali come very rarely into close contact with sheep and goats, on the contrary to urial in the Hindu Kush range of Wakhan. Based on the results of serology, range use measurements and wildlife-livestock cohabitation studies we concluded that urial in Wakhan is the wild ungulate species of highest risk to be infected by PPRV transmitted by sheep and goats excreting the virus.



Plate 3. In Wakhan National Park urial sheep (*Ovis orientalis*) may come in close contact (<100 m) with livestock, making them particularly at risk of being infected by pathogens excreted by domestic stock, Hindu Kush Mountain Range, Wakhan National Park. Credit: @Stephane Ostrowski / WCS Afghanistan

Mitigating the risk of peste des petits ruminants outbreaks in wildlife of Wakhan

WCS has developed in Wakhan a holistic conservation approach that involves community conservation, conservation education and awareness, protection resulting in increase of size and genetic values of populations of wild ungulates and their predators, promoting a sustainable use of rangeland, developing sustainable livelihood resources, and improving animal health practices. When combined these actions contribute to reduce the likelihood and impact of disease spillover from livestock to wildlife. We present here only animal health-focused actions (see conclusion for further development).

Improving animal health capacity and disease surveillance

In Afghanistan animal health activities are conducted by a range of actors involving state veterinary authorities, private and community paraveterinarians trained by the Dutch Committee for Afghanistan (DCA), a variety of NGOs, and in the recent past foreign military forces. In general, livestock vaccination is one of the main activities of these actors, a commitment that is achieved with variable efficiency according to the capacity of vaccinators, to the remoteness of targeted areas, the availability of a cold chain and

adequate storage facilities. The Aga Khan Foundation (AKF) promotes veterinary activities in Afghanistan and particularly in the province of Badakhshan. A veterinary health center was established in Ishkashim District, adjacent to the Wakhan District, and staffed with Afghan and Tajik veterinary practitioners. They have been actively vaccinating livestock against a variety of diseases in Ishkashim and Zebak districts. Yet, until recently little and only sporadic efforts have been devoted to implement animal health activities within the remote Wakhan District, mainly because of logistical difficulties, the lack of capacity and the chronic difficulty at establishing a reliable cold chain, essential to store drugs and particularly vaccines before use. A livestock research center supported by Aga Khan Development Network was established in the early 2000's in Khandud, the capital of Wakhan District, but has remained underequipped and has been active irregularly and according to staff availability.

In 2007, WCS sponsored the training by DCA of the two first paraveterinarians in the area and operationalized two field veterinary units in Abgarch and Kandkhan villages, respectively, in Upper Wakhan. These two paraveterinarians also received training specific to wildlife health, and reporting disease outbreaks in livestock and/or wildlife has been a mandate of their activities. Since 2010 AKDN sponsored the training of additional paraveterinarians and by the end of 2016, there were eight paraveterinarians and associated field veterinary units in Wakhan in the villages of Qazideh (1), Yamit (1), Khandud (2), Avgarch (1), Kandkhun (1), Ptukh (1), and Chilkand (1). A veterinary doctor hired from Tajikistan supervises the six paraveterinarians managed by AKDN. Their main duties are to deliver basic curative services, assist livestock parturitions in cases of complication, and undertake vaccinations. In 2013 and 2014 WCS organized seminars on wildlife disease, and detection courses for 14 paravets in Wakhan (8), Ishkashim (3) and Zebak (3) districts.

Finally since the beginning of WCS work in Afghanistan in 2006, WCS has involved collaboratively and supported field missions in Wakhan of the veterinary staff of the Ministry of Agriculture in Feyzabad, Badakhshan. Training courses on wildlife health have also been delivered in Kabul to more than 150 veterinarians and paraveterinarians from at least 14 provinces, and all PPR serological investigations were carried out at the Central Veterinary Diagnostic and Research Laboratory of the General Directorate of Animal Health and Production in Kabul in collaboration with foreign trainers and reference laboratories.

Vaccination of livestock

In support of the creation and management of the Wakhan National Park in 2014, the Wildlife Conservation Society in partnership with the government and local communities have identified the main Wakhan Valley as the main axis of propagation of PPR in the park. It has also been shown that the urial population in the Hindu Kush Mountain Range

of the park is the most at risk of spillover contamination from infected sheep and goats. Finally because the disease is responsible episodically of high sheep and goat mortality and mountain ungulates species present in Wakhan have been shown to be susceptible to PPR, vaccination of sheep and goats in the Wakhan National Park was identified as a useful prophylactic measure to mitigate the risk of PPR outbreak in the protected wildlife populations under recovery.

WCS developed a sheep and goat PPR vaccination plan for the period 2017 – 2019. In 2017 this initiative benefitted from a national vaccination campaign organized by the Afghan government in extensive areas of Afghanistan and executed in the Wakhan District by paraveterinarians supported by AKF. These paravets vaccinated during summer 2017 approximately 36,000 sheep and goats in the park, mainly in Pamirs and lower Wakhan. The two paravets supported by WCS accompanied by staff from the veterinary department of the Ministry of Agriculture office in Feyzabad, Badakhshan, vaccinated an additional 8,117 sheep and goats between October 13th and November 6th. They used a commercially available attenuated vaccine (Pestevac, JOVAC, Jordan, a freeze dried live attenuated PPR vaccine strain Nig 75/1) that elicits a protective immunity that has been shown to be effective for at least three years post-vaccination (Sen et al. 2010). This second vaccination operation was implemented along the Wakhan Valley in selected villages adjacent to important urial habitats in lower Wakhan, and in villages of upper Wakhan that bring most of their sheep and goats to Pamirs during summer. Prior to this vaccination effort WCS staff sampled 331 sheep and goats randomly selected across the Wakhan Valley and tested them serologically for exposure to PPR. Twenty-three sheep and goats tested positive, or a pre-vaccination PPR prevalence of 6.9% (CI95% 4.2%-9.7%), aligned with results of earlier investigations in Wakhan. A post-vaccination random testing will be carried out in 2019, at the end of the vaccination plan, to evaluate the effectiveness of the vaccination. WCS will continue and increase the vaccination efforts in autumn 2018 and 2019.

A transboundary perspective

The Wakhan National Park shares far more boundaries with Tajikistan, Pakistan and China than with Ishkeshim District, the only adjacent district in Afghanistan. Although the western part of Wakhan is bordered by the almost impassable Hindu Kush mountains to the south and the wide Panj River to the south, several high passes in the eastern Hindu Kush and Karakoram ranges in eastern Wakhan enable the movement of people and livestock between Afghanistan and Pakistan, while the open landscapes of Pamirs offer relatively easy passages between Afghanistan and Tajikistan (the few high passes between Afghanistan and China are either inaccessible or fenced and thoroughly controlled by Chinese border guards). These mountain passes are regularly used by Wakhi visitors from Pakistan to visit their relatives in Afghanistan, and Kyrgyz of Little Pamir are allowed to

batter goods and livestock with traders from Pakistan over accessible passes (Callahan 2013).

In a unique effort to improve the scientific knowledge on animal health in transboundary Pamirs, a three-country international project involving the Wildlife Conservation Society, and the University of Veterinary and Animal Sciences, Lahore, Pakistan, as principal partners was undertaken between March 2011 and May 2012. The project contributed to merging the technical capacities of three leading veterinary diagnostic entities in Afghanistan, Tajikistan and Pakistan within one transboundary livestock screening initiative. After being introduced to the concept of ecosystem health and after agreeing on consistent methodologies, collaborators organized field missions in the Pamirs landscape within each of their three countries in the summer of 2011 and collected a total of 2,339 sera samples from sheep and goats. These samples were successfully analyzed at respective national laboratories for seroprevalence to brucellosis and contagious caprine pleuropneumonia according to standardized methods (Peyraud et al. 2014). During a final workshop that took place in Dushanbe, Tajikistan, on 5-7 March 2012, results of these analyses were extensively discussed in order to help partners begin to consider and plan for health issues within a transboundary, One Health, paradigm. During the workshop the opportunity was taken to expose regional participants to international experts in the field of infectious diseases and build their capacity through technical training in the field of serodiagnostics. At the end of the workshop a number of recommendations were offered by participants and a transboundary institutional collaboration was initiated (Ostrowski et al. 2012).

Conclusion and lessons learned

The epidemiology of PPR in Central Asian highland is still poorly understood. More research is needed to understand on a longer time scale the means and circumstances of PPR outbreaks in livestock living under considerable environmental stress (altitude, climate, physical effort) and exposed to many other pathogens. In particular the role of yak will need further examination to rule out the species as a possible PPRV excreting organism. Although the role of domestic sheep and goats as the main mean of introduction of the disease into populations of susceptible wildlife is largely accepted worldwide more studies have to be carried out on the circulation of the virus amongst wildlife and the possibility for the virus to re-infect secondarily livestock.

Countries in Central Asian highlands share thousands of km of inaccessible and remote international borders, usually very difficult to control. The transboundary movement of livestock in eastern Wakhan is only one example of a common situation in the region. It however demonstrates the continuing need for active surveillance to be improved in Central Asian highlands to provide real-time monitoring of PPRV circulation and to

disclose more effectively the links between outbreaks. There is also a great need of coherent animal health collaboration between adjacent countries. An extensive vaccination effort, such as initiated in the Wakhan National Park, will reach long term success only if remote communities across the border in Tajikistan, Pakistan and China implement similar control efforts. The means of PPRV transport between countries needs to be better studied and in particular the role played by wild ungulate populations has to be assessed. This information is needed as a prerequisite for further development of regional control programs. Pakistan, and China, with their large livestock populations are expected to play a major role in PPR control in this part of the world.

Control of PPR in this very remote part of Asia will have to be based on a considerable effort in capacity building at community and local animal health service levels. In Afghanistan the backbone of epidemiological surveillance is the network of paraveterinarians, yet their reporting and reaction capacities are still in their infancies and will require in the years to come considerable more training, staffing and funding. The support of NGOs in this respect is essential as they can provide the necessary mentorship on the ground and support, when necessary, the paravets. In Wakhan for example, owing to the relative lack of cash in the area and to the reluctance of livestock owners to pay for animal health services, few of the paraveterinarians can afford to be full-time active at improving animal health; the one in Qazideh, without equipment, is jobless and the others divide their time between animal health work and other livelihood options, only two of them spend the majority of their time in veterinary occupations. It is however essential to nurture the capacity and interest of the other ones and strengthen their connection to the 'health network' by providing regular sponsored refresher training courses and contracting them for health work such as vaccination campaigns.

In the Central Asian context of generalized increasing encroachment of livestock into wild habitats, livestock are the prime target for disease surveillance schemes as they are the most likely source of disease spillover to wild ungulates. Moreover, livestock can be responsible for upslope range-shift of mountain ungulates into less suitable, stressful foraging habitat. Therefore controlling the risk of PPR outbreaks in mountain wildlife requires a complex and holistic approach that enforces prevention of disease spillover from livestock to wild ungulates and implements multifaceted controls over livestock numbers and their range use. Limiting other controllable stressors (such as human disturbance), and whenever possible maximizing genetic variability of small, fragmented wildlife populations through enhanced subpopulation connectivity are also recommended to reduce disease susceptibility. Vaccination of livestock is not a *panacea*. On one hand when inefficiently implemented (e.g. faulty vaccine storage) it could give a false impression to herders that livestock is safe and protected and on the long term undermine the trust of local people in vaccination that is traditionally regarded with suspicion. On the other hand when efficiently implemented,

vaccination may further enhance encroachment of livestock into wild ungulate habitat and nutritional competition, as a consequence to increased livestock survival and productivity. The resulting overgrazing would also seriously impact local economies and people's wellbeing. Therefore health managers should tend to prioritize measures that limit contacts between livestock and wild ungulates, that favor a sustainable use of pastures, that limit stress level of wild ungulates and maximize their genetic values, and that favor disease detection and reporting, rather than invest only on prophylactic actions on livestock.

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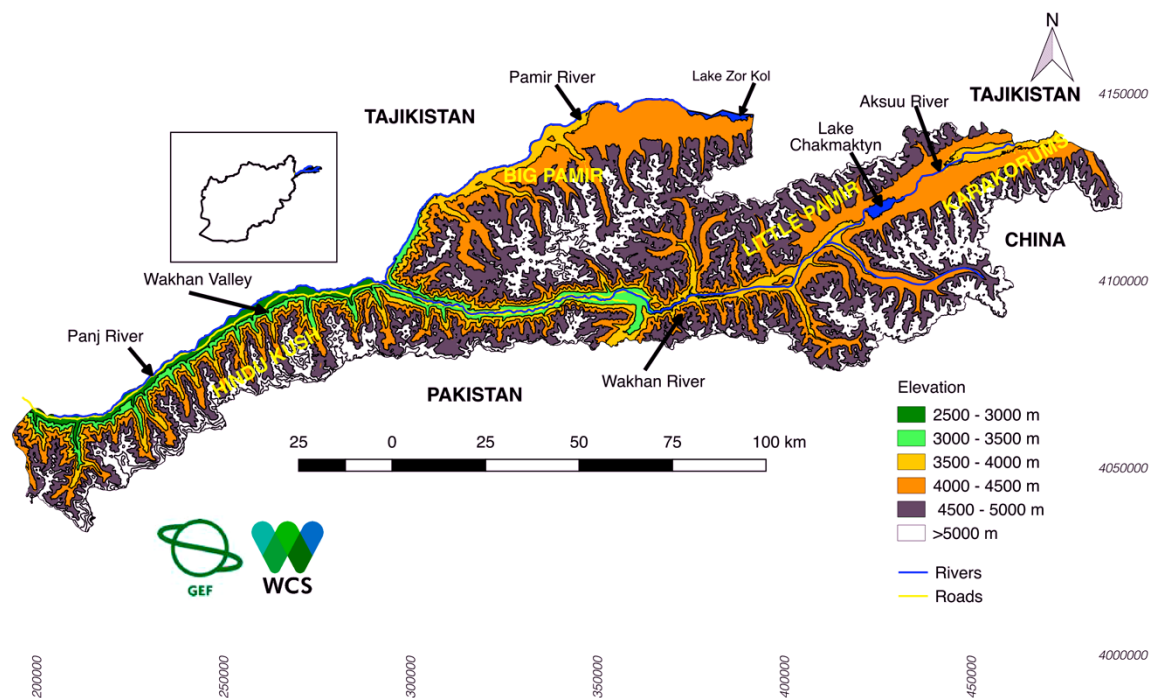


Figure 1. Overview map of Wakhan National Park (extracted from Wakhan National Park draft Management Plan, 20 September 2017).

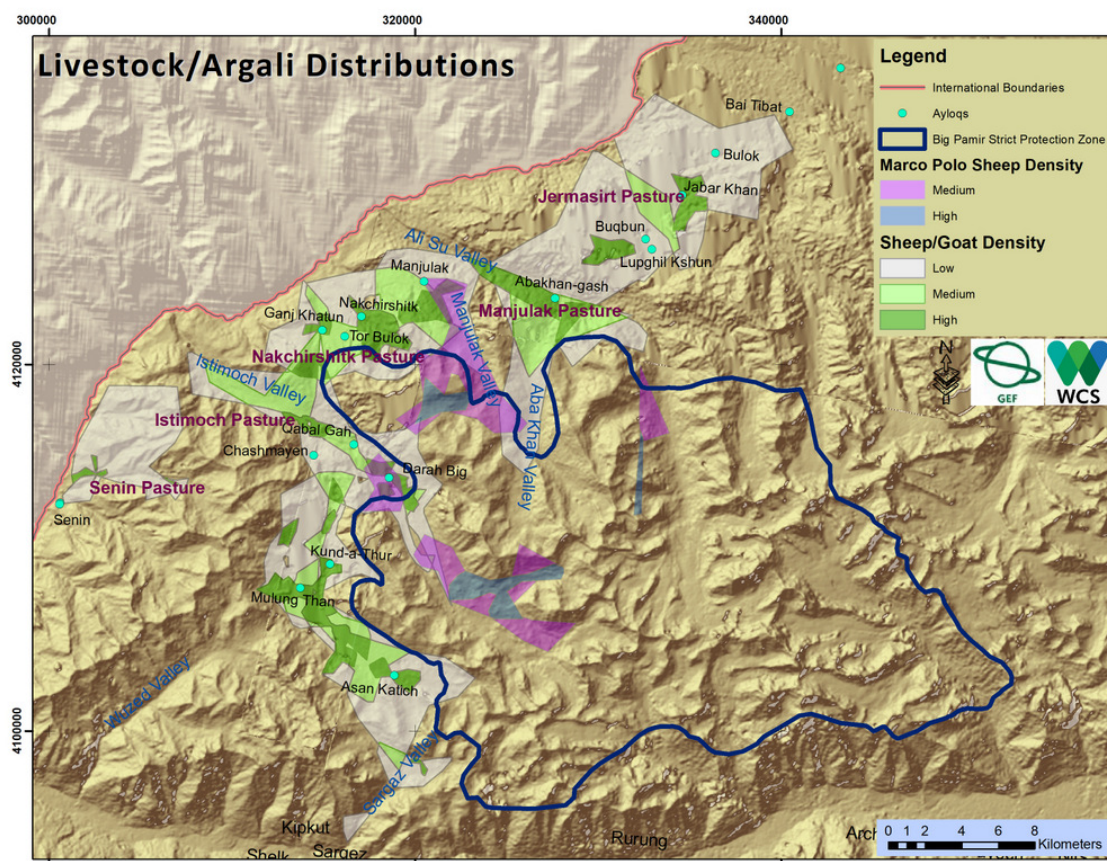


Figure 2. A map showing the areas of contact and of spatial overlap between sheep/goats and argali (*Ovis ammon*) in May – October in Big Pamir, Wakhan National Park, Afghanistan. Spatial overlaps were not concomitant.