

PPR Episystems Update

A Management Tool to Guide PPR Eradication

Jeffrey C. Mariner Veterinary Epidemiologist

PPR Episystems

Episystems: A Management Tool to Guide Eradication

A virus episystem is a set of interconnected host population capable of maintaining circulation and transmission of the virus indefinitely

The role of specific populations in the episystem determines when, where and how actions should be taken to achieve eradication

Management and monitoring should be based on the episystem and the strategy to interrupt virus circulation in the episystem.



Core populations

- The core of an episystem is the population components capable of sustaining PPR virus transmission over prolonged periods – the reservoir
 - For PPR Domestic small ruminants
 - Often remote or marginalized communities
 - Surveillance and disease reporting databases often misleading
 - Northern Kenya



Incidental Infections - Periph populations

- **Outbreaks spillover from** system
- Lower density/contact •
- **Periodic re-introduction** •
- Not all susceptible spec • transmit PPR to the ext role in enabling virus m
 - Cattle
 - Wildlife
 - Camels

Mesno 2 North Wello Kobo Addis kegn(05) 3 North Wello Afaf Kobo Addis Alem (07 4 North Wells Kobo Afafe (022 Afat Arabiti 5 South Welld Arehal Werehabo 6 South Wello Chali Werebabo China 7 North Wello Tis Keye Were Lalo 8 North Wello Jarota Kule Habru Mehal Amba 9 North Wello Mehal Amba Habru Dire Roka Kilewa 10 North Wello Habri 11 Oromia Special zone Bat Chekorti Fara 12 Oromia Special zone Bat Felana Weyo Filana 13 Oromia Special zone Bati Chachatu Cha Chatu 14 Oromia Special zone Bati Sukai Salmene 15 North Shoa Kurebere Kure berel 16 North Shoa Sefiberet Sefiberetina 17 North Shoa Madina Kewe Medina 18 North Shoa Yelen Kewe Veler

Kobo

Dibi (011)

1 North Wello







Kebele boundary Woreda boundar

Zone boundary

> BMC Vet Res. 2019 Mar 8;15(1):84. doi: 10.1186/s12917-019-1828-6.

These are dead Molecular detection and phylogenetic analysis of

PAs2007 Weyiru Dikalo

contribute to v Peste des petits ruminants virus circulating in small ruminants in eastern Amhara region, Ethiopia

> Biruk Alemu¹, Getachew Gari², Geneviève Libeau³, Olivier Kwiatek³, Menbere Kidane⁴, Rediet Belayneh⁴, Bewuket Siraw⁵, Barbara Wieland⁶, Wondwoson Asfaw⁷, Reta D Abdi⁸



PPR Episystems

Agree on simple terminology

The reservoir in the system is those populations that are required to maintain transmission of the virus

- Reservoir populations
- Core

Other populations in the system that may become periodically infected but cannot maintain infection

- Peripheral
- Incidental

Issue of Scale

- Local episystems Uganda and Bangladesh stable clusters
- Regional episystems China-Mongolia interactions over distance
- Supra regional?



The Structure of Episystems

An episystem:

- May consist of one large population but more commonly consists of several interlinked sub-populations
- Small ruminant holdings of an ethnic community often share common herding and contact patterns and can be considered a population
- Movement and transhumance over a geographical area is often a feature that must be considered
- Can include value chains or marketing chains
- Can be a network of populations at different locations and not necessarily in a contiguous zone

Episystems typically transcend international borders and often involves more than one regional economic community





Episystems vs. Risk-Based Approaches

- The episystem approach is based on an understanding of the epidemiological patterns of disease transmission:
 - Direct evidence of disease transmission
 - Descriptions of patterns
 - Case and outbreak detection and investigation
 - Cluster analysis
 - Triangulated with risk factors
- Risk-based approaches utilize risk data as surrogates for direct evidence
 - A more probabilistic approach
 - Inferred patterns from circumstantial evidence
- Risk-based vaccination is not episystems targeted vaccination





Drivers of Episystems

- *Viral* attributes such as host range, receptor affinity, transmission rates, etc.
 - Viral attributes also evolve in the face of selective pressure.
- Host
 - individual and population
- Environment
 - Climate
 - Landscape
- Society, culture, political economy, production systems all shape ecosystems and episystems.
 - host population structure, mobility and the environment

Interrelated and Dynamic





PPR Episystems

Episystem description and assessment

- The heart of assessing national PPR epidemiology (Stage 1)
- Conventional and participatory epidemiological characterization of:
 - Populations, contact patterns, outbreak patterns
- Analysis of the genetic sequence and clustering (molecular epidemiology) of strains detected in an episystem are:
 - The best epidemiological tool to delineate systems
 - Easily achievable if appropriately planned
 - Internationally available servicess for testing and analysis





Examples of PPR Episystems

Karamoja Karamojong cluster

- Areas of Uganda, Kenya, South Sudan and Ethiopia
- Herds of Turkana, Karamojong, Jie, Dodoth, Toposa, Nyangatom and Pokot
- Defined homestead areas with complex transhumance and livestock exchange patterns





Epidemiological Mapping

- Focus group of key informantson the ground
- Interactive list epidemiological factors
- Groups map factors
- Like layers in a GIS
- Exam the patterns and areas of intensity of factors



Episystem Map Layers

- Populations and their interactions
 - Livestock and wildlife
 - Density and intensity of interactions
 - Critical community size
- Movement pathways and seasonal congregations
- Past epidemiological patterns
- Vaccination levels and gaps
- Insecurity
- Linkages to other systems

Goat Density in 2010

Number of goats per square kilometre in 2010



FAO 2010

Examples of Episystems







Regional Episystems Meeting Ulaanbataar, April 2025

Examples of PPR Episystems

Molecular epidemiology to define drivers of the system

Partial N gene sequences

- Looro and Kamion clusters
- Separated by ~125 kms
- Clusters more closely related to other areas of East Africa than each other
- Two separate systems?



Participatory Assessments – Hypothesis and validation

- The outcome of the initial assessment is working hypothetical scenario and map of the reservoir and and incidentally affected populations.
- This hypothesis is validated through participatory field assessments of the component populations.
- The participatory assessments will gather local knowledge (livestock owner and professional) on the patterns of PES events.
 - Some communities have specific names for PPR.
- Ideally, the field assessments will lead to the detection of cases and additional virological and molecular data that confirm or refute the initial hypothesis.
- Usually the outcome is a refinement of the working hypothesis.





Holistic analysis

- Strengths of Alemu et al
- Targeting of study location
- Case finding in the field
- Genetic analysis
- Challenges Alemu et al highlight
 - Fragmentation of analysis
 - National borders and now state borders
 - Incomplete understanding of episystem
 - Core reservoir not identified
 - Leading to Ineffective recommendations





FIGURE 2 | Map of West Africa showing sampling location according to their PPRV lineage II genetic cluster. Dots represent location of samples obtained for this study. Rectangles indicate countries of origin for publically available sequence data used in this study and belonging to genetic clusters of interest in this study. Dots and rectangles are colored according to the genetic cluster (C1 to C5) they were placed in by phylogenetic analysis (see Figure 1). Black dots represent PPRV Regional Episystems Meeting Ulaanbataar, April 2025

Planning strategies

Which are the core populations?

Which are the peripheral populations?

Where do you focus vaccination to stop the cycle?

The 20:80 rule: 20% of the population accounts for 80% of the transmission



Second Introduction of PPR to China - 2014



Was the source Central Asia?

Evolution – What factors affected the distribution of outbreaks?



First PPR Introduction to Mongolia



Pruvot et al., 2020

Regional Episystems Meeting Ulaanbataar, April 2025



First PPR Introduction into Mongolia

- Isolates Cluster with China
- Most common ancestor analysis finds Mongolian livestock isolates predate Mongolian wildlife isolates (Benfield et al., 2021)
- Mongolia developed an NSP focused on control in the Western regions
- Mongolia outbreaks in subsequent years in Central and Eastern regions

Pruvot et al., 2020

• Re evaluate the episystem analysis

- KX664097.1 /PPRV/China/XJ/KC/2016 KM091959.1 /PPRV/China/XJYL/2013 KM232748.1 /PPRV/China/AHFT/2014 KP868655.1 /PPRV/CH/GDDG/2014 KX938427.1 /PPRV/China/XJNJ/2014 MF443352.1 /PPRV/ChinaGD2014 KY434304.1 /PPRV/Xinjiang 2015-61 MF072382.1 - PPRV/Mongolia/1/2016 MF072380.1 - PPRV/Mongolia/3/2016 MF072379.1 - PPRV/Mongolia/4/2016 MF072377.1 - PPRV/Mongolia/5/2016 MF072376.1 - PPRV/Mongolia/10/2016 KM232750.1 /PPRV/China/XJYL/2013 KP319027.1 /PPRV/China/Shaanxi/2014 KT895431.1 /PPRV/GD/PY/2014 KX664100.1 /PPRV/China/XJ/Urumugi/2016 China/Mongolia MF443351.1 /PPRV/ChinaGS2014 KY434292.1 /PPRV/Xinjiang 2015-45 KY434289.1 /PPRV/Xinjiang 2015-42 KY434284.1 /PPRV/Xinjiang 2015-36 KT633939.1 /PPRV/China/XJBZ/2015 - KX664096.1 /PPRV/China/XJ/SS/2014 MF443353.1 /PPRV/ChinaCQ2014 KX421384.1 /PPRV/China/2/2013 KY434285.1 /PPRV/Xinjiang 2015-37 KY434283.1 /PPRV/Xinjiang 2015-35 KY434287.1 /PPRV/Xinjiang 2015-39 KX421386.1 /PPRV/China/4/2013 MF443354.1 /PPRV/ChinaAH2014 KT895430.1 /PPRV/GD001 PPRV/Mongolia/saiga8.1/N/2017 Saiga PPRV/Mongolia/Saiga5/N/2017 KY429031.1 /PPRV/Wuwei nucleocapsid KY550670-Iran/BH11/16-2 /2015 - DQ840198-Tajikistan/04 GQ122187-Dindori 08-goat JF939201.1 /PPRV/China/Tib/07 EU340363-Tibet0702-China KC207885-Pakistan/MM79/camel/2012

Regional Episystems Meeting Ulaanbataar, April 2025



OR286484.1 PPRV/Mali/Sagabari/10/2014 OR286483.1 PPRV/Senegal/Pakour/2/2013 OL310685.1 PPRV/DRC/Tshela/27/2012 KF727981.2 Sungri/96 OL310695.1 PPRV/Israel-1277/Jordan-Valley/2004 OL310694.1 PPRV/Israel-2233/Beir-El-Makhsour/2003 OL310688.1 PPRV/Israel-4522/Tzora/1998 OL310687.1 PPRV/PPRV/Israel-2536/Hebron/1997 KR140086.1 (zatriagan/94 OR286504.1 PPRV/India/Calcutta/1995 NC006383.2 Turkey 2008 MK408669.1 Kurdistary2011 MN657232.1 Turkey/Central Anatoka/2018 MF737202.1 Georgia/Tollisi/2016 ON110960.1 PPRV/Ethiopia/Habru/2014 KJ867541.1 Ethiopia 2010 KY885100.1 S15 KC594074_1 Morocco 2008 MG581412.1 PPRV/Bangladesh/BD2/2008 OK274214.1 PPRV/Bangladesh/BD17/2017 OK274213.1 PPRV/Banglades/VBD12/2015 KT860063.1 IND/TN/VM/2014/02 88 KR261605.1 India/TN/Gingee/2014 F3905304.1 China/Tibet/Geg/07-30 JF939201 1 China/Tib/07 KX421388.1 China/33/2007 JX217850.1 Tibet/Bharal/2008 PP937138.1 ChinaTibet2024 KM091959.1 China/XJYL/2013 KP260624.1 China/8J/2014 KY888168.1 PPRV/Mongolia/9/2016 KX421384.1 China/2/2013 KX421385.1 China/3/2013 KX421386.1 China/4/2013 KX421387.1 China/5/2013 MF443336.1 ChinaYN2014 MF443335.1 ChinaZ32014 MF443337.1 ChinaSX2014 MF443338.1 ChinaSC2014 MF443339.1 ChinaSaX2014 MF443340.1 ChinaNX2014 MF443341.1 ChinaLN2014 MF443342.1 ChinaJX2014 MF443343.1 ChinaJS2014 MF443344.1 ChinaJL2014 MF443345.1 ChinaHN2014 MF443346.1 ChinaHLJ2014 MF443347.1 ChinaHeN2014 MF443348.1 ChinaH82014 MZ061719.1 PPRV/saiga3/Mongolia/2017-01 MZ061720.1 PPRV/saiga4/Mongolia/2017-01 MZ061721.1 PPRV/Siberian ibex/Mongolia/2017-01 OP066374.1 PPRV/China-HL3/01/2013 MZ051722.1 PPRV/Goltered gazelle/Mongolia/2017-01

Tro

IV

78

49

73

91

91

56

81

91

95

97

Jiao Xu et al., 2024

- Rutong County, Tibet
- Bharals and Argali
- Clusters closely with 2013-14
 strains



PPR Episystems

The Role of Participatory Epidemiology and Molecular Epi

- Understand risk from the ground up
- Triangulation of information
 - Multiple methods and multiple sources
 - Timelines and maps of past outbreaks
 - Diverse types of information
 - Includes biological test data
 - Interactive epidemiological mapping
- Best bet scenario for the episystem
- Testing episystem hypotheses through molecular epi
 - Cluster analysis
 - Ancestor analysis and divergence timelines





Management of Eradication

Management based on episystems elimination

- Vaccination should be targeted to the interlinked reservoir communities
- Vaccination should be implemented simultaneously across all reservoir populations in the episystem
- Vaccination methods should be appropriate to the community
- Goal of 80% herd immunity within one vaccination campaign
- Suboptimal vaccination coverage can favor persistent endemism
- Non-reservoir, incidentally infected populations are best protected by eliminating the virus reservoir. Scattering of resources leads to failure.
- Surveillance to validate the episystem assessment, measure progress and detect changes in the episystems
- Management, monitoring and evaluation all based on the episystems present
- Performance indicators monitor on the actions based on the episystems assessments
- Episystems, action plans and monitoring plans updated annually



Thank you