OIE/FAO Foot-and-Mouth Disease Reference Laboratory Network

Annual Report 2019

Editors:

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Maps within this document

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Abyei: Final status of the Abyei area is not yet determined.

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Contents

1 OIE/FAO FMD Reference Laboratory Network

1.1 Principle Goals

The Network of OIE/FAO FMD Reference Laboratories has been established with two principal goals:

1) To understand global virus distribution patterns and use these data to inform vaccine recommendations

and

2) To harmonise and improve the quality of laboratory testing carried out by international and national reference laboratories.

These activities require sharing and joint evaluation of surveillance information from laboratory diagnosis, serotyping, genetic characterisation and vaccine matching tests and harmonisation of standards for diagnostic procedures.

This report is divided into two parts providing an update on progress towards each of these goals.

1.2 Reporting Period

1st January 2019 - 31st December 2019

1.3 Collated input from

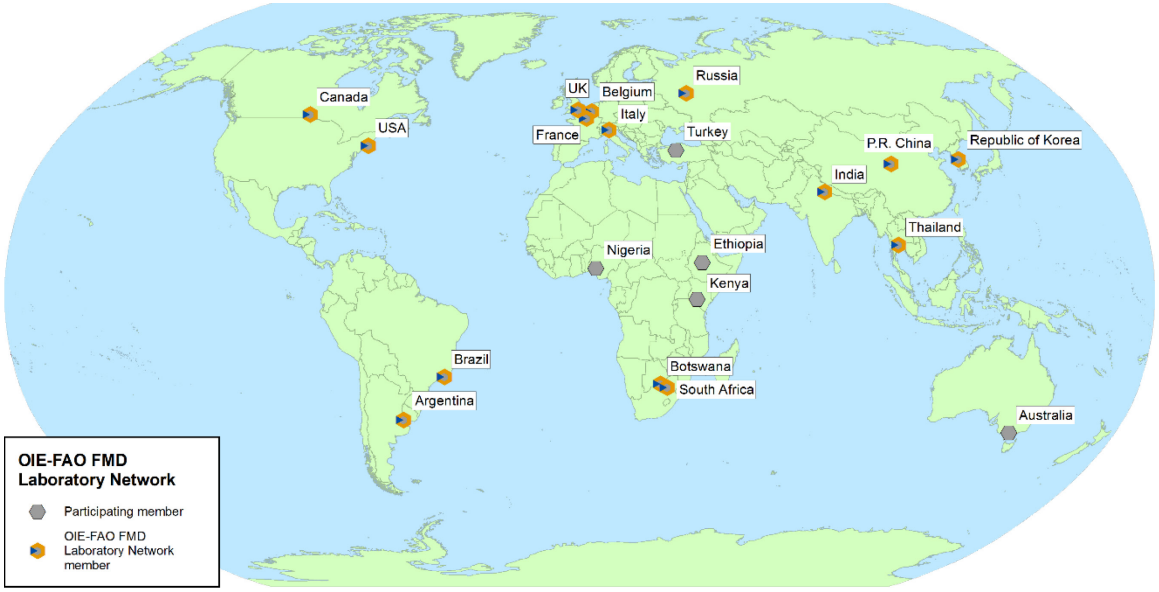


Figure 1.1: Participating laboratories

OIE Reference Laboratory for Foot and Mouth Disease, Dirección de Laboratorio Animal

SENASA, Argentina

OIE Regional Reference Laboratory for Sub-Saharan Africa (RRLSSA)

BVI, Gaborone, Botswana

FAO FMD Reference Laboratory

National Centre for Foreign Animal Disease National Centres for Animal Disease, Canadian Food Inspection Agency, Winnipeg, Manitoba, Canada

OIE FMD Reference Laboratory

French Agency for Food and, Environmental and Occupational Health & Safety (ANSES), Maisons-Alfort, Paris, France

OIE/FAO FMD Reference Laboratory

Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia Romagna (IZSLER), Italy

OIE collaborating centre for validation, quality assessment and quality control of diagnostic assays and vaccine testing for vesicular diseases in Europe, and FAO Reference Centre for vesicular Diseases

Sciensano, Ukkel, Belgium

Centro Panamericano de Fiebre Aftosa (PANAFTOSA) and OIE Reference Laboratory for FMD

Rio de Janeiro, Brazil

OIE and China National FMD Reference Laboratory

Lanzhou Veterinary Research Institute (LVRI), CAAS, Gansu, People's Republic of China

FAO Reference Centre for FMD in South Asia

ICAR – Directorate of Foot-and-Mouth Disease, Indian Council for Agricultural Research, Mukteswar, Nainital (Uttarakhand), India

OIE Reference laboratory for Foot and Mouth Disease

Animal and Plant Quarantine Agency (QIA), Anyang city, Gyeonggi-do, Republic of Korea

FAO Reference Centre for FMD for Central Asia and West Eurasia and OIE Reference Laboratory for FMD

Federal Governmental Institute, Centre for Animal Health (FGI ARRIAH), Vladimir, Russian Federation

OIE Regional Reference Laboratory for Foot and Mouth Disease in the South East (RRLSEA)

Department of Livestock Development, Pakchong, Thailand

FAO Reference Centre for FMD and other vesicular diseases for the Americas and the Caribbean and OIE FMD Reference Laboratory

Foreign Animal Disease Diagnostic Lab, Plum Island Animal Disease Center (PIADC), Greenport, United States of America

FAO Reference Laboratory for FMD in Africa and OIE FMD Reference Laboratory

Transboundary Animal Diseases Programme, ARC-Onderstepoort Veterinary Institute (ARC-OVI), South Africa

FAO World Reference Laboratory and OIE FMD Reference Laboratory

The Pirbright Institute Pirbright, Surrey, United Kingdom

Additional input kindly supplied by:

Australian Animal Health Laboratory (AAHL)

Geelong, Australia

Foot and Mouth Disease Laboratory

Embakasi, Kenya

Şap Institute (and WELNET FMD)

Ankara, Turkey

NATIONAL Animal Health Diagnostic & Investigation Center (NAHDIC)

Sebeta, Ethiopia

National Veterinary Research Institute

Vom, Plateau State, Nigeria

2 Genetic and antigen diversity and global distribution of foot-and-mouth disease viruses

Foot-and-mouth disease (FMD) is a highly contagious viral disease that infects a wide variety of domestic and wild cloven-hooved hosts. Its presence impacts upon rural livelihoods and restricts trade opportunities for countries where the disease is endemic, and poses a constant threat to those countries that are free of the disease. In endemic countries, the economic costs associated with FMD are estimated to be US$6.5–21 billion annually, with outbreaks in FMD-free countries and zones potentially causing economic losses of >$1.5 billion. FMD virus lineages are not randomly dispersed throughout the world but are associated with particular ecological niches. The distribution of these FMD virus lineages is affected by cyclical upsurges in the prevalence of particular strains that may be associated with the evolution of FMD viruses to escape protective immunity in susceptible livestock populations and/or opportunities presented by movements of animals and their products. These features can give rise to pandemic events where FMDV lineages spread widely to affect new regions.

Global surveillance for FMD is necessary to identify the current hazards and to predict heightened risk so that appropriate diagnostic tools and vaccines are available for detection and control. This requires sustained effort directed towards the monitoring of FMD outbreaks and ideally also of FMDV circulation and persistence, along with collection and characterisation of FMD viruses and integration of findings with associated epidemiological intelligence. Such an extensive effort requires a coordinated approach encompassing national and international disease laboratories of the **OIE/FAO FMD Laboratory Network** (www.foot-and-mouth.org) along with partnering laboratories, commercial vaccine and diagnostic providers. The worldwide distribution of the different serotypes and variants of FMD virus (as compiled in 2019) and the associated activities of the Network laboratories are presented in this report.

2.1 Introduction

Global surveillance undertaken by the OIE/FAO FMD Laboratory Network aims to monitor the distribution of FMD viruses to predict risk for endemic and FMD-free countries. FMDV is unevenly distributed throughout the world reflecting factors such as livestock density and species mix, patterns of husbandry, animal movement and trade, wildlife reservoirs and incentives and capacities for disease control. The virus exists as seven serotypes and multiple subtypes where cross-immunity is absent or incomplete. The situation is dynamic and complex and affected by viral evolution, waxing and waning of host immunity and changing ecosystems and trading patterns. Despite the opportunities for spread of FMDV into new regions, viruses tend to recur in the same parts of the world, presumably reflecting some degree of either ecological isolation or adaptation. On this basis, the global pool of FMD viruses can be subdivided into seven ‘regional pools’ in which genetically and antigenically distinctive virus strains tend to occur within a defined region.

The seven ‘Regional Pools’ referred to throughout this report are shown below (Figure 2.1) and represent:

Pool 1	Southeast Asia with spill over into Eastern Asia
Pool 2	Southern Asia
Pool 3	Western Asia with spill over into North Africa
Pool 4	Eastern Africa with spill over into North Africa
Pool 5	Western Africa
Pool 6	Southern Africa
Pool 7	South America

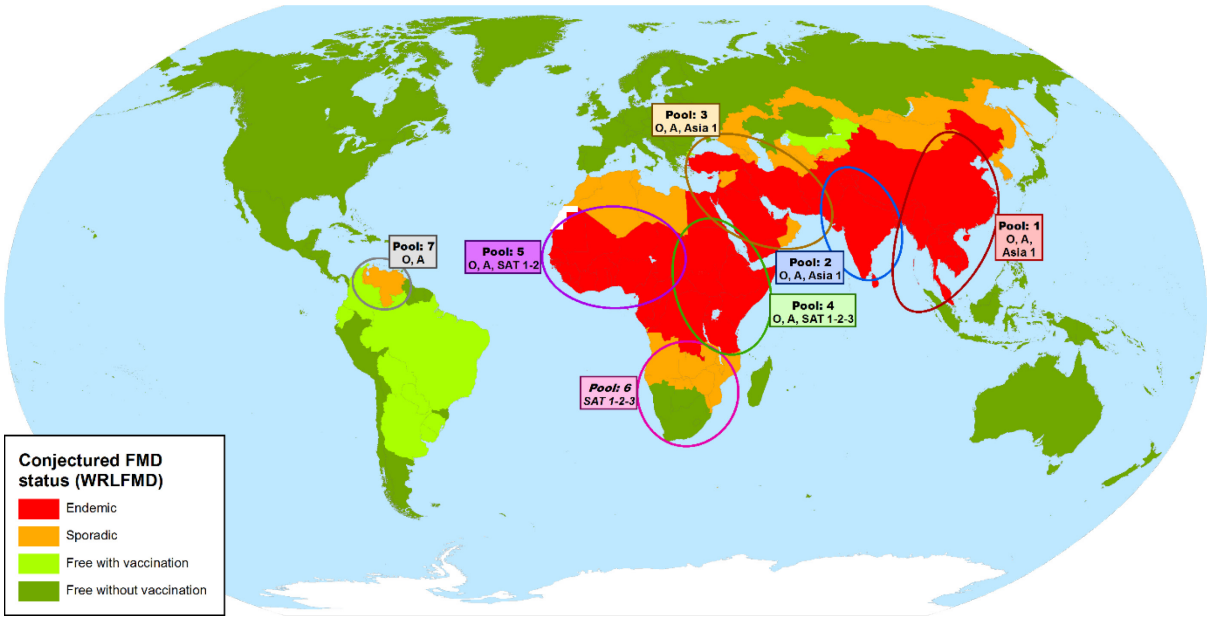


Figure 2.1: Distribution of the seven endemic pools of FMD showing conjectured status of FMD in countries during 2019. Periodically, viruses spread between pools and to free regions, and countries at the interfaces between pools (such as in North Africa and Central Asia) often experience FMD outbreaks from different regional sources. Note on Pools 4-6: In Africa there are currently three FMD virus pools loosely defined as covering East Africa (pool 4), West Africa (pool 5) and Southern Africa (pool 6). A map describing the official OIE status for these countries can be found at: https://www.oie.int/en/animal-health-in-the-world/official-disease-status/fmd/en-fmd-carte/.

The clustering of FMD viruses into 7 virus pools, with 3 pools covering West Eurasia, South Asia and Southeast Asia, 3 pools covering East, West and Southern Africa and 1 pool covering the Americas, is now enabling a targeted approach to be applied to the ‘Progressive Global Control of FMD’ initiative overseen by the OIE and FAO and for which the Network laboratories will play a pivotal role.

Overview of the Global situation in 2019

Key headline events (highlighted in Figure 2.2):

- As in past years, serotype O is the predominant serotype followed by serotype A.
- Further expansion of the O/ME-SA/Ind-2001e lineage during 2019 into Pakistan. These new outbreaks raise concern as it is the first time that this lineage has been detected in a West Eurasian country (except for a single report in 2009 for a sample collected from Iran) that has the potential for onward spread into countries such as Iran and Turkey.

- Continued outbreaks of O/EA-3 (2018/19) in North Africa (Libya and Morocco) following on from cases due to A/AFRICA/G-IV during 2017. There are now two distinct viral lineages responsible for the cases detected in North West Africa (Maghreb) and North East Africa (Egypt). The shipment of these samples has been difficult and alternative methods have been used to characterise FMD viruses such as lineage specific rRT-PCR, and transfection methods for "live" virus recovery from RNA.
- New outbreaks of O/EA-2 in central Zambia and Comoros have been caused by two different lineages (15% nt difference). The Comoros lineage is most closely related to samples collected in Tanzania. The Zambia outbreaks appear to represent a southern movement of the virus.
- An outbreak of SAT 2 in South Africa has resulted in a suspension of FMD-free status
- Retrospective data confirms the presence of the SAT 1 lineage X in Cameroon in 2016.
- There has also been a new incursion of SAT 2/VII lineage into Egypt – most closely related to sequences from Ethiopia.

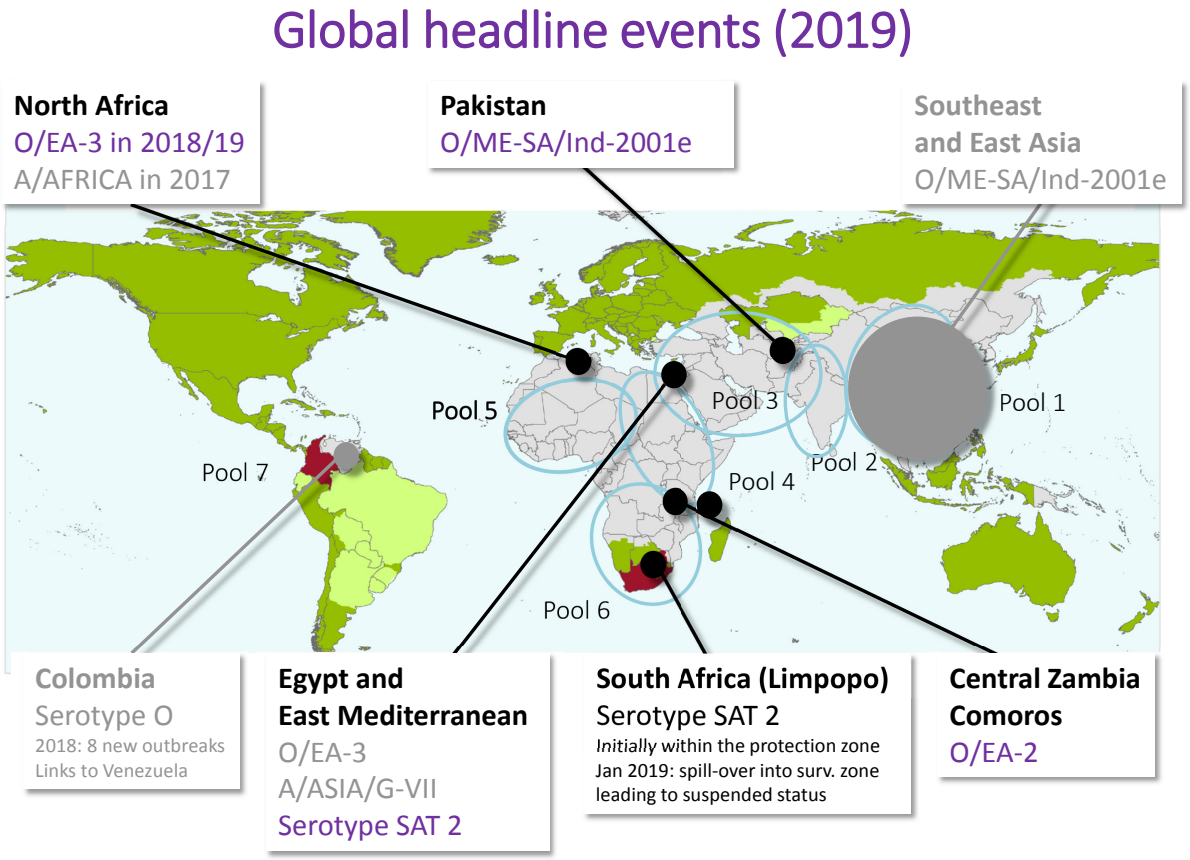


Figure 2.2: Headline FMD events for 2019 (highlighted in purple – important epidemiological events from 2018 are also shown in grey)

Specific information regarding contemporary FMD outbreaks can be found on the World Animal Health Information Database (WAHID) located on the OIE website (http://www.oie.int/wahis_2/public/wahid.php/Wahidhome/Home), as well as the EMPRES Global Animal Disease Information System (http://empres-i.fao.org/) provided by FAO. Further supplementary data and updates are generated on a monthly basis by EuFMD (http://www.fao.org/ag/againfo/commissions/eufmd/commissions/eufmd-home/fmd-surveillance/situation-reports/en/).

During 2019, FMD outbreaks have continued to affect countries in the established endemic regions of the world. Particular attention has been focussed upon new FMD outbreaks and

events that have occurred at the margins of these endemic regions (reported on the OIE WAHIS Interface: http://www.oie.int/wahis_2/public/wahid.php/Wahidhome/Home/indexcontent/newlang/en, summarised in Figure 2.3 and described elsewhere in this report). *Additional disease outbreaks in countries in the FMD endemic pools have also been reported to OIE during 2019 (data collated in Table 2-1).*

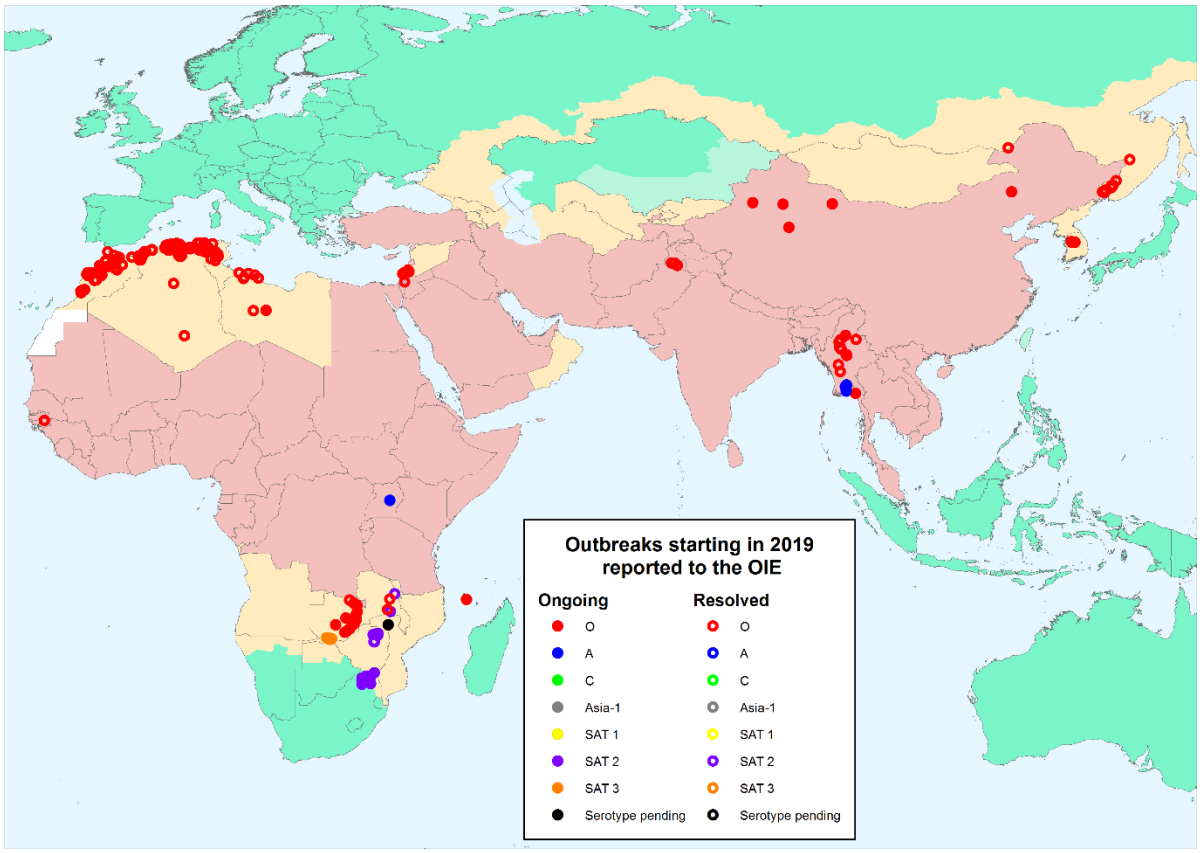


Figure 2.3: Map indicating the location of significant epidemiological events and disease outbreaks reported to OIE in immediate notifications or follow-up reports in 2019 (data available from: http://www.oie.int/wahis_2/public/wahid.php/Diseaseinformation/Immsummary.

Further details of many of the characterisation of viruses retrieved from these outbreaks are provided later in this report.

Table 2-1: New FMD outbreaks reported to OIE during 2019 (data retrieved from WAHIS on www.oie.int on 5th June 2020). Note: not all outbreaks shown in Figure 2.3 are collated in this table and data may be incomplete

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Afghanistan	9	14	13	19	31	37	...						123
Algeria	149	17	5				...						171
Bangladesh	+						+						0
Benin	1	2			3		...						6
Bhutan	10						3						13
Burkina Faso	3				2	1	...						6
Cambodia	2	1	1	17	1	4				2	5		33
Central African Republic	+..						+..						0
Congo (Dem. Rep. of the)	3						...						3
Cote D'Ivoire	1						...						1
Egypt	19	12	8	1			...						40
Eritrea		1		1				1	5	2		2	12
Guinea	3	4	4	1	3		...						15
Guinea-Bissau	2	1	2	1			...						6
Hong Kong (SAR - PRC)			2	2	3		0						7
Iran	1069						...						1069
Iraq	4	8	15	1	3	2		1	3	1	4	4	46
Israel	2	1			1		...						4
Kenya	2				10			11	10	20	3	2	58
Laos	7	29	16				...						52
Libya				2	7		0						9
Malaysia	7	4	2	2	4	1	...						20
Morocco	19	11	4	5	6		...						45
Mozambique					1		...						1
Myanmar	1						...						1
Nepal	19	29	20	3	7	4	7	3	6	3	3	2	106
Niger	?						...						0
Nigeria						2	...						2
Oman	+						...						0
Pakistan	1284						529						1813

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Palestinian Auton. Territories				1						...			1
Qatar				...						3			3
Russia	12	4	1							0			17
Saudi Arabia	+									...			0
Somalia				1						4			5
South Africa	5									...			5
Sudan				2								1	3
Tanzania	2	3	1	1	3	4	6	5	5	3	5	2	40
Thailand	6	1	2	2	4	4	3	4	3	38	66	58	191
Tunisia	5	2								...			7
Turkey	6	30	34	4	8	4	2	4	3	4	15	11	125
United Arab Emirates				1						0			1
Vietnam	6		1	4						...			11
Zimbabwe	2		20	7		1				...			30

Key to symbols:

0 *Continuing previous outbreak (s)*
... *No information available for this disease*
0 *Disease absent*
? *Disease suspected but not confirmed*
+? *Confirmed infection/infestation without clinical signs*
+.. *Disease present but without quantitative data*
+ *Disease present with quantitative data but with an unknown number of outbreaks*
+() *Disease limited to one or more zones*
+?() *Infection/Infestation in one or more zones*
?() *Disease suspected but not confirmed limited to one or more zones*

2.2 Overview of the activities of the OIE/FAO FMD Laboratory Network during 2019

The OIE/FAO FMD Reference Laboratory Network provides important support to the global control of FMD and provides opportunities and expertise for developing and sustaining laboratory capacity and capability, exchange of materials and technologies, harmonising approaches to diagnosis and supporting complementary research. Laboratories within the Network regularly receive samples for FMD diagnosis from many parts of the world. The *in vitro* antigenic properties of selected isolates are assessed for vaccine matching and nucleotide sequencing allows precise characterisation of new isolates and tracing of their origin by comparison with viruses held in virus collections. This analysis assists the monitoring of the 'real time' emergence and spread of FMD virus globally.

1627 clinical samples from suspect cases of FMD were tested by laboratories in the Network (and associated laboratories) during 2019. These samples were collected from 40 countries from all seven FMD endemic pools (Figure 2.4). **However, sampling within these pools is not equivalent:** and efforts are currently underway with the Network to improve sample collection in regions where sampling is particularly under-represented.

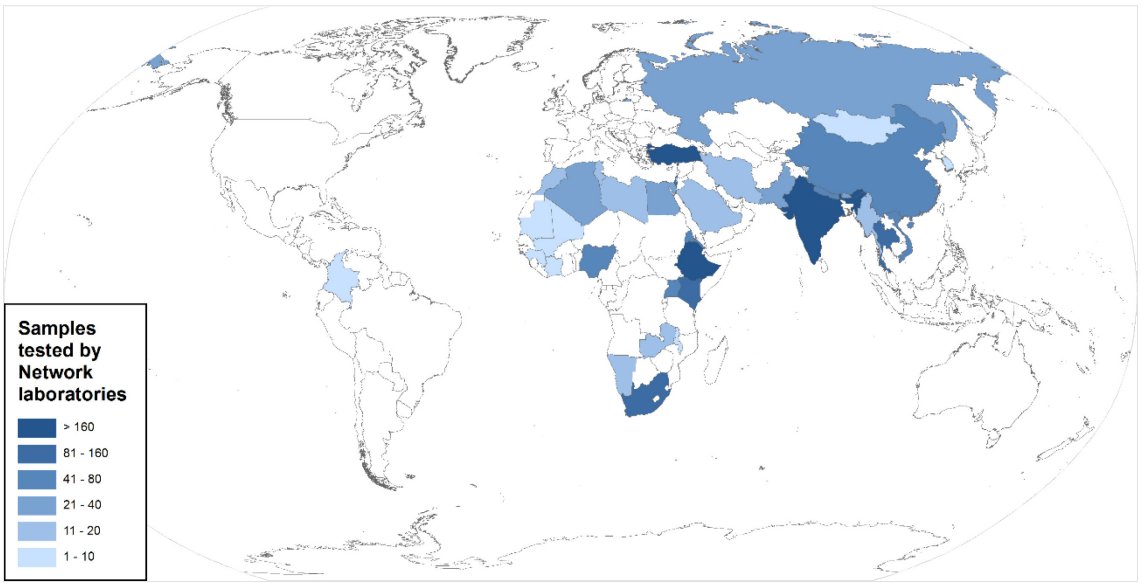


Figure 2.4: Distribution of samples collected from suspect cases of FMD and tested by the OIE/FAO FMD Laboratory network during 2019. Routine surveillance that is undertaken in countries that are FMD-free without vaccination is not shown

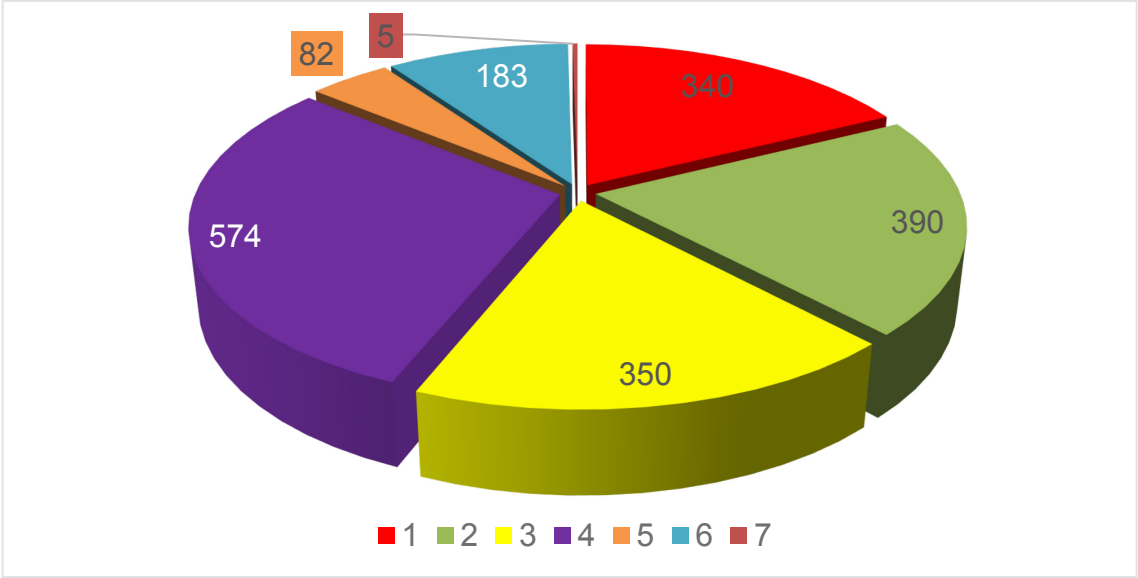


Figure 2.5: Clinical samples (n=1933) tested for FMD investigation (virology) by the OIE/FAO FMD Laboratory Network from FMD endemic countries during 2019 and their distribution across the seven FMD endemic pools (see Figure 2-1)

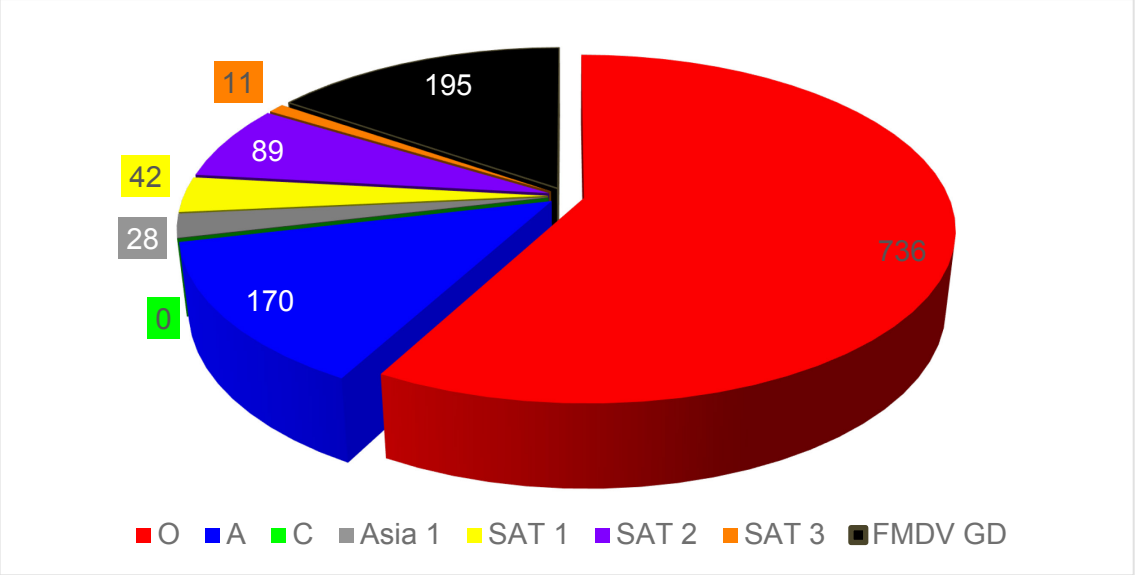


Figure 2.6: Summary of results for characterised isolates (n=1629) from FMD endemic countries were reported by the Network during 2019. FMDV GD denotes samples that were only positive using molecular (RT-PCR methods), while a further 505 samples were tested but found to be negative for FMDV using all diagnostic methods.

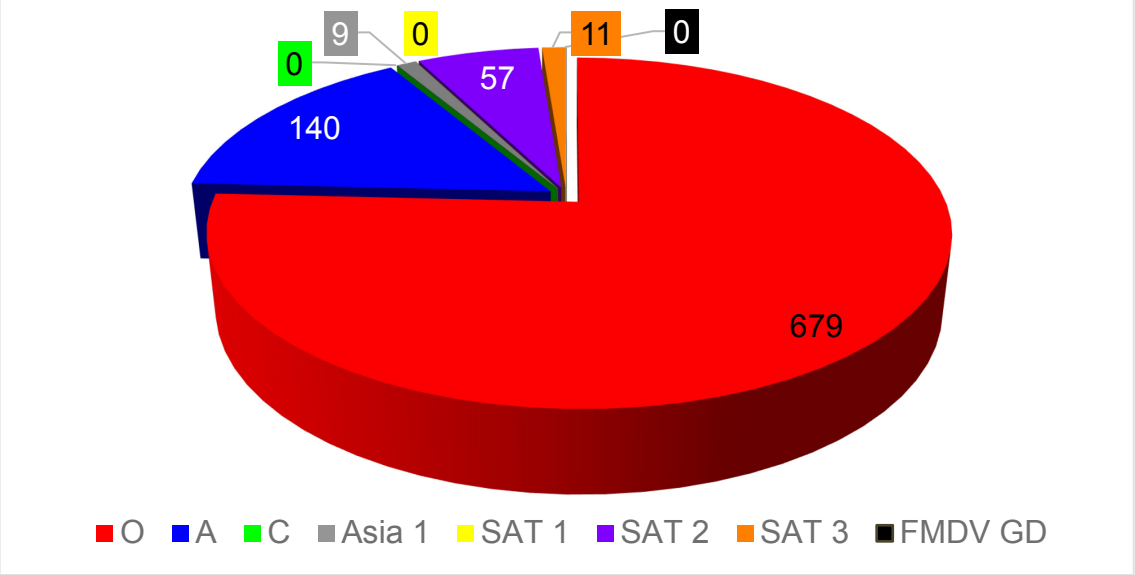


Figure 2.7: Summary of 864 samples (viruses and field isolates) that were sequenced (VP1/capsid/complete genome) during 2019 (see Appendix 3).

The results for the individual samples are reported later in this report. It is also important to note that a much larger number of samples (such as sera, OPF and lymph node samples) were also received and tested by laboratories within the network during this period for surveillance activities: these numbers are also summarised in the tables for each of the individual endemic pools. Characterization results obtained on samples received by WRLFMD and PANAFTOSA can also be found respectively at: http://www.wrlfmd.org/ and at: http://new.paho.org/panaftosa.

2.3 Regional distribution of different FMD viral lineages

In regions where FMD is endemic, continuous evolution of the virus generates geographically discrete lineages that are genetically distinct from FMD viruses found elsewhere. The conjectured global status for FMD (see Figure 2.1) masks the underlying complexity of FMDV virus distribution in the different pools (at serotype, topotype and lineage levels). This report showcases a new format to display how different FMD lineages ciruculate in different regions of the world. Using a new tool (called PRAGMATIST) that has been developed in partnership between WRLFMD and EuFMD, analyses accommodate the latest epidemiological data collected by the Network and presented in this report regarding FMDV lineages detected in samples to assess the relative importance of the viral strains circulating within each *source regions* (see Table below). Based on these data, a *prevalence score* is defined by estimating the proportion of each of the local viral strains that would be represented if 100 animals infected with FMDV were randomly selected from each source area.

Table 2-2: Conjectured distribution of important FMDV lineages in different endemic regions. For each of the regions, data represent the relative importance of the different lineages [prevalence score estimated as a proportion (%) of total FMD cases that occur in domesticated host animals]. NB: Arrows highlight recent changes

FMDV lineage	West Eurasia	East Asia	North Africa	Southern Asia	East Africa	West and Central Africa	Southern Africa	South America
O/ME-SA/PanAsia-2	↓ 35	-	-	-	-	-	-	-
O/ME-SA/PanAsia	-	↑ 10	-	-	-	-	-	-
O/SEA/Mya-98	-	↓ 33	-	-	-	-	-	-
O/ME-SA/Ind2001	↑ 6	20	↓ 10 $_{35}$	80	-	-	-	-
O/EA or O/WA	↑ 3	-	↑ 55 $_{20}$	-	↑ 55 $_{45}$	↑ 70 $_{37}$	-	-
O/EURO-SA	-	-	-	-	-	-	-	↑ 80 $_{74}$
O/CATHAY	-	10.5	-	-	-	-	-	-
A/ASIA/Sea-97	-	↓ 25	-	-	-	-	-	-
A/ASIA/Iran-05	↓ 25.5	-	-	-	-	-	-	-
A/ASIA/G-VII	↓ 17.5	-	-	16	-	-	-	-
A/AFRICA	-	-	↓ 25 $_{35}$	-	↓ 22 $_{24}$	↓ 15 $_{25}$	-	-
A/EURO-SA	-	-	-	-	-	-	-	↓ 20 $_{26}$
Asia-1	↓ 12.5	↓ 1.5	-	4	-	-	-	-
SAT 1	-	-	-	-	↓ 8 $_{10}$	↓ 5 $_{10}$	27	-
SAT 2	↑ 0.5	-	10	-	↓ 14 $_{20}$	↓ 10 $_{28}$	57	-
SAT 3	-	-	-	-	1	-	16	-
C	-	-	-	-	-	-	-	-

In order to help visualise the changing patterns in FMDV distribution and recognise risks for the emergence of new lineages, the Network has reviewed available intelligence for epidemiologically important FMDV lineages (**Error! Reference source not found.**), focussing on those that have already demonstrated a potential for long-distance trans-pool spread: O/ME-SA/Ind-2001, O/ME-SA/PanAsia, O/ME-SA/PanAsia-2, O/SEA/Mya-98, O/EA-3, A/ASIA/G-VII, A/ASIA/Iran-05, A/ASIA/Sea-97 and SAT 2/VII.

The current known and conjectured distribution of these different FMD viral lineages are represented in the maps below: The extent of current distribution for each of the viral lineages is represented within the black lines, while the location of individual outbreaks (dots) and affected countries (shaded colours, according to dates) are shown. NB: Arrows are drawn to highlight the regions that are now threatened by these lineages and text boxes highlight some of the headline events and changes that have occurred during 2019

FMDV O

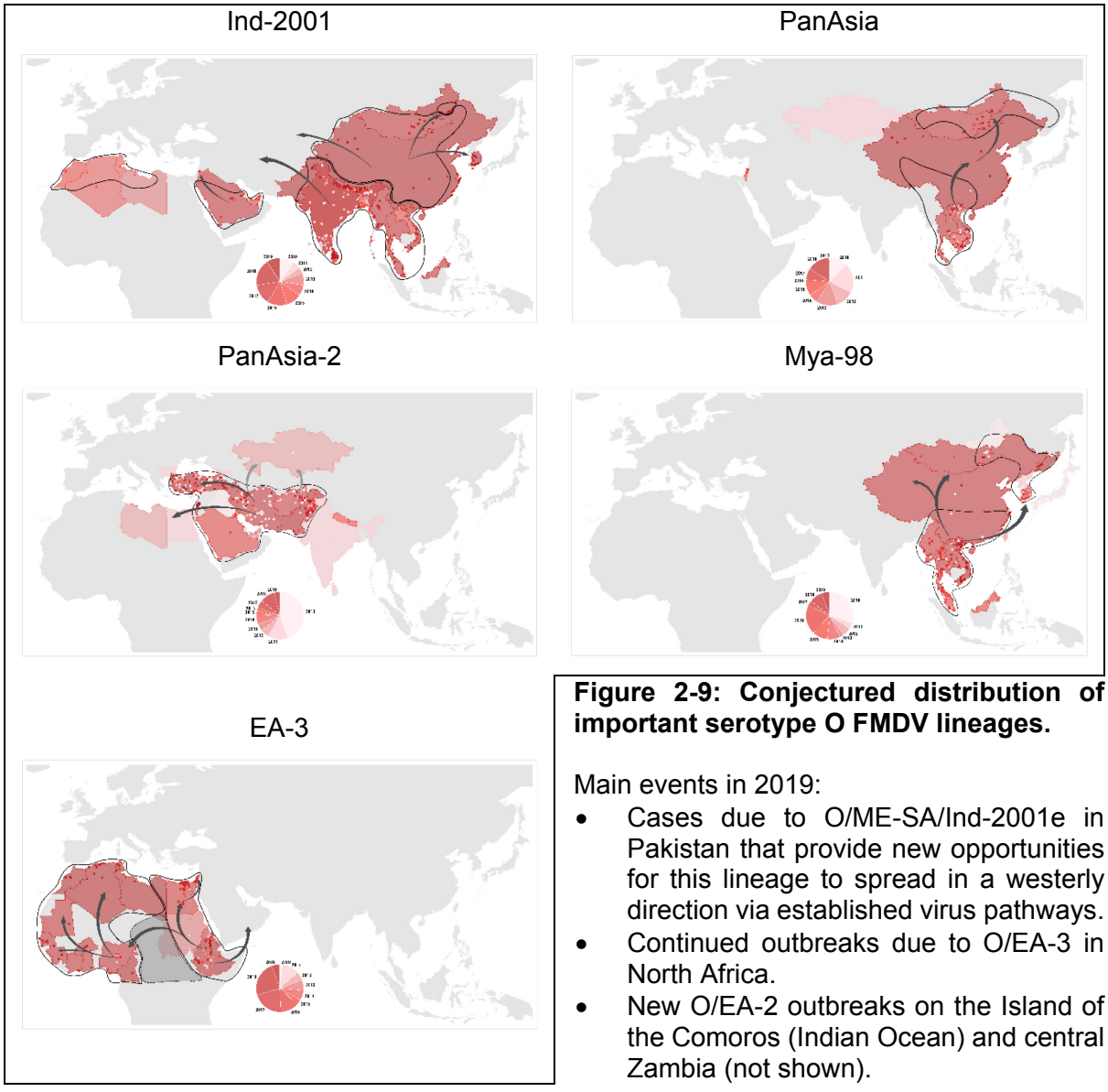


Figure 2-9: Conjectured distribution of important serotype O FMDV lineages.

Main events in 2019:

- Cases due to O/ME-SA/Ind-2001e in Pakistan that provide new opportunities for this lineage to spread in a westerly direction via established virus pathways.
- Continued outbreaks due to O/EA-3 in North Africa.
- New O/EA-2 outbreaks on the Island of the Comoros (Indian Ocean) and central Zambia (not shown).

FMDV A

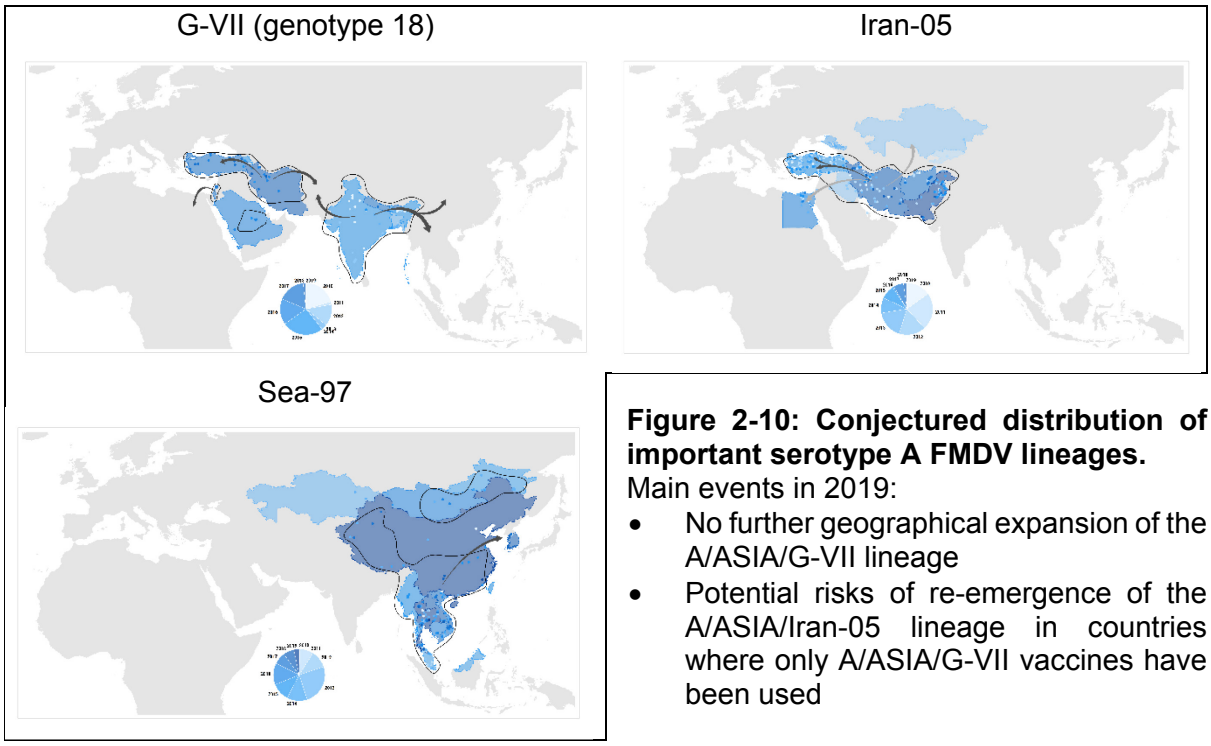


Figure 2-10: Conjectured distribution of important serotype A FMDV lineages.
Main events in 2019:

- No further geographical expansion of the A/ASIA/G-VII lineage
- Potential risks of re-emergence of the A/ASIA/Iran-05 lineage in countries where only A/ASIA/G-VII vaccines have been used

FMDV Asia 1

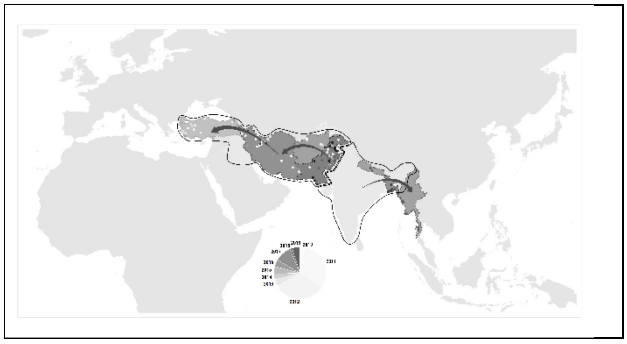


Figure 2-11: Conjectured distribution of serotype Asia 1.
Main events in 2019:

- No further spread of this serotype in Southeast Asia (beyond cases reported in 2017)

FMDV SAT 2

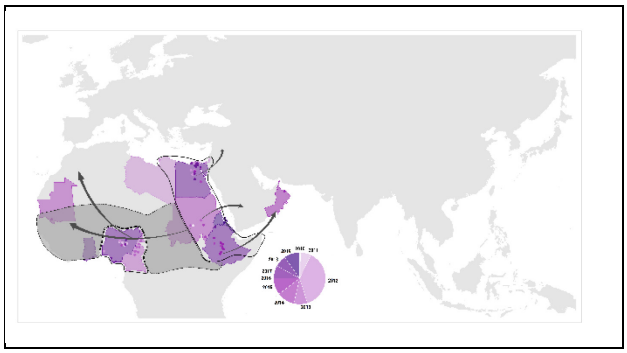


Figure 2-12: Conjectured distribution of serotype the SAT 2 (topotype VII) FMDV lineage.
Main events in 2019:

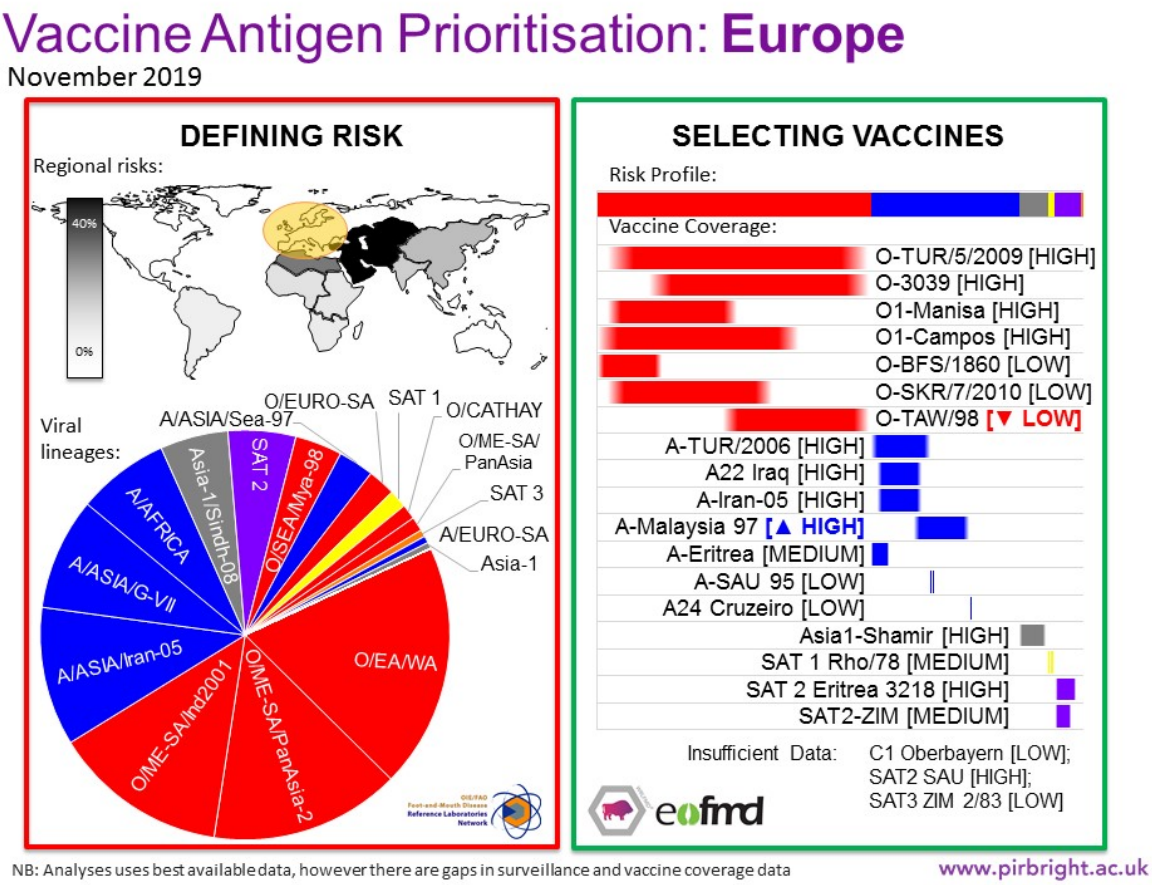
- New incursion into Egypt
- Potential for this serotype to spread from West Africa into North Africa (paralleling the incursions of A/AFRICA/G-IV (in 2017) and O/EA-3 (in 2018/19).

2.4 Vaccine matching and recommendations

These take two forms: regional recommendations and details of locally produced vaccines for each of the FMD endemic pools are summarised later in this report, whilst the WRLFMD recommendations for FMD free countries are given in **Error! Reference source not found. Error! Reference source not found.**. Details of vaccine matching work undertaken by the OIE/FAO FMD Laboratory Network are summarised in Appendix 2 - .

Outputs from WRLFMD are generated with a new tool (called PRAGMATIST) that has been developed in partnership between WRLFMD® and EuFMD. These analyses accommodate the latest epidemiological data collected by the Network regarding FMDV lineages that are present in different source regions (see **Error! Reference source not found. Error! Reference source not found.**), as well as available *in vitro*, *in vivo* and field data to score the ability of vaccines to protect against these FMDV lineages. Further information about FMD vaccine producers is available on the Network website: https://www.foot-and-mouth.org/fmd-vaccine-producers

Table 2-3: Recommendations from WRLFMD on FMD virus strains to be included in FMDV vaccine antigen bank for Europe



The figure highlights the importance of these source regions for Europe (using data collected at the EU-RL Workshop); please contact WRLFMD/EuFMD for assistance to tailor these outputs to other geographical regions. NB: Vaccine-coverage data presented is based on available data and may under-represent the true performance of individual vaccines.

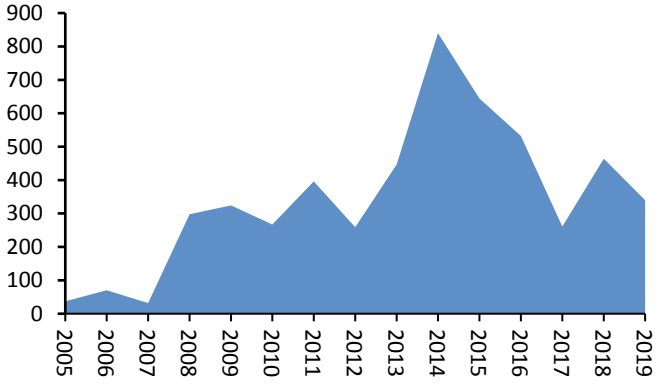
3 Overview of Network surveillance activities in each of the regional endemic pools

3.1 Pool 1 Regional synopsis

3.1.1 Conjectured circulating FMD viral lineages in Pool 1 during 2019

- Serotype O:
  - SEA/Mya-98
  - ME-SA/PanAsia
  - ME-SA/Ind2001d
  - ME-SA/Ind2001e
  - CATHAY
- Serotype A:
  - ASIA/Sea-97
- Serotype Asia-1 (no outbreaks detected since 2017, Myanmar)

Table 3-1: Overview of clinical samples collected and tested from Pool 1 in 2019 (countries highlighted in blue; graph represents clinical submissions since 2005)



Laboratory	Countries of Origin	Number of Samples	
		Clinical Field Cases	*Surveillance Activities*
SENASA, Argentina	Vietnam	0	26
LVRI, China	China	76	5350
APQA, Republic of Korea	Republic of Korea	3	556344
FGBI ARRIAH, Russia	Russia	28	43254
RRL SEA Pakchong, Thailand	Thailand	118	6059
WRLFMD, UK	Hong Kong, Mongolia, Myanmar, Republic of Korea, Thailand, Vietnam	115	0

Pool 1 headlines:

- Serotypes O & A are endemic in the Southeast Asia region. No new/unexpected lineages were identified in this region during 2019.
    - On-going surveillance and investigation of outbreaks have demonstrated that five virus lineages are present in China (O/CATHAY, O/ME-SA/Ind-2001e, O/SEA/Mya-98, O/ME-SA/PanAsia and A/ASIA/Sea-97 – highlighting the continued connectivity to countries in mainland southeast Asia (see Figures A4.1. and A4.2 for phylogenetic trees for O/ME-SA/PanAsia and O/ME-SA/Ind-2001 and A/ASIA/Sea-97).
    - New outbreaks due to O/ME-SA/Ind-2001e in South Korea and Zabaikalsky, Russia (Figure A4.3).
    - In Russia, outbreaks due to O/SEA/Mya-98 reported in Primorsky (Figure A4.4) and O/ME-SA/Ind-2001 in Zabaikalskiy (Figure A4.5).
- No new outbreaks due to serotype Asia1 were detected in 2019. This serotype has been absent since 1998, with the exception of outbreaks in Vietnam (2006) and Myanmar (2017).

3.1.2 Vaccine recommendations for Pool 1

- Internationally produced vaccines:
    - O: Campos, Manisa, Primosky & 3039
    - A: Arg2001, A24 Cruzeiro, Iraq/64, Malaysia/97, Zabaikalsky& A22-IRQ.
    - Asia 1: Shamir
- Locally produced vaccines (at RRL SEA):
    - O: 189/87 (Udornthani/87)
    - A: Lopburi/12, Sakolnakorn/97
    - Asia1: Petchaburi/85
- Locally produced vaccines (at FGBI ARRIAH):
    - O: Ind-2001d, Mya-98, PanAsia, PanAsia-2
    - A; G-VII, Iran-05, Sea-97
    - Asia1: Shamir, Sindh-08
- Locally used vaccine strains (by Chinese manufactures):
    - O/Mya-98 (O/Mya98/BY/2010 and Re-O/Mya98), O/HK99
    - Re-A/Sea-97 (Re-A/WH/09)
    - Asia1/GV (Asia1/JSL/06).

These are produced as: Type O and Type A (monovalent vaccines), Type O-A and Type O-Asia1 (bivalent vaccine), Type O-A-Asia1 (multi-valent vaccine) and a synthetic peptide vaccine (Type O for use in pigs only). In China vaccination occurs 2 times a year (in spring and autumn), where more than 1 billion doses are produced and administered per year.

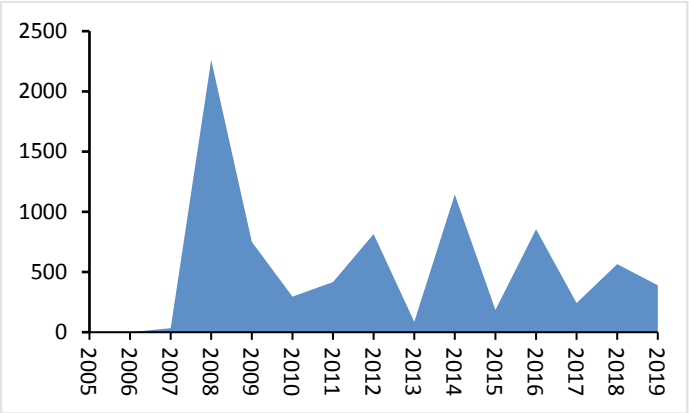
3.2 Pool 2 Regional synopsis

3.2.1 Conjectured circulating FMD viral lineages in Pool 2 during 2019

- Serotype O:
    - ME-SA/Ind-2001
    - ME-SA/PanAsia-2 (last detected in 2011 in Sri Lanka)
- Serotype A:
    - ASIA/IND (genotype VII also known as genotype 18)

- Serotype Asia-1:

Table 3-2: Overview of clinical samples collected and tested from Pool 2 in 2019 (countries highlighted in blue; graph represents clinical submissions since 2005)



Laboratory	Countries of Origin	Number of Samples	
		Clinical Field Cases	*Surveillance Activities*
ICAR-DFMD, India	India	306	0
WRLFMD, UK	Bhutan, Nepal	84	0

Pool 2 headlines:

- All FMDV-positive samples collected from Bhutan represented the O/ME-SA/Ind-2001e lineage highlighting the continued dominance of this lineage in Pool 2

3.2.2 Vaccine recommendations for Pool 2

- Internationally produced vaccines:
  - O/ME-SA/PanAsia-2 (or suitable alternative). *In vitro* vaccine matching data for O/ME-SA/Ind2001 provides evidence for an antigenic match with O/TUR/09 vaccine (MSD) and O-3039 (Boehringer Ingelheim).
- Locally produced vaccines (by Indian suppliers):
  - O/IND/R2/1975
  - A/IND/40/2000
  - Asia1/IND/63/1972

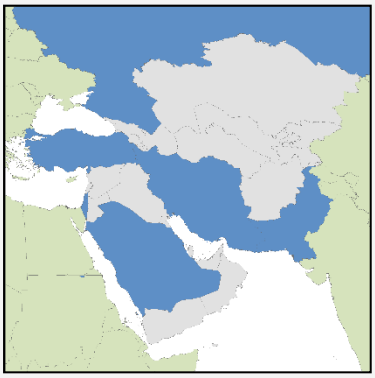
3.3 Pool 3 Regional synopsis

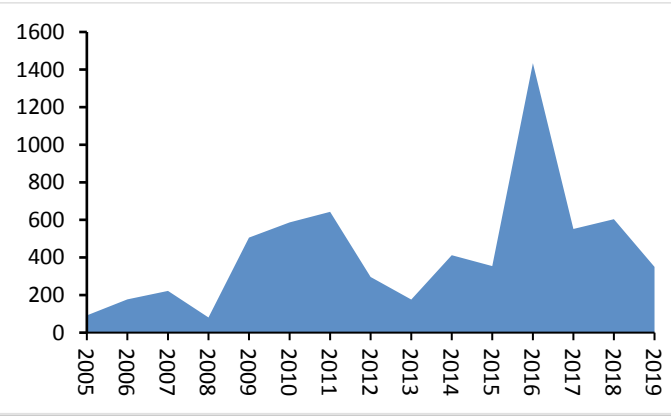
3.3.1 Conjectured circulating FMD viral lineages in Pool 3 during 2019

- Serotype O:
  - ME-SA/PanAsia-2 [comprising at least two viral sublineages (ANT-10 and QOM-15) present in different countries].
  - ME-SA/Ind-2001 (via introductions from South Asia)
  - EA-3 (in Israel & Palestinian Autonomous Territories)
- Serotype A:
  - ASIA/Iran-05 [comprising 4 predominant viral sublineages (SIS-10, SIS-12, SIS-13 and FAR-11)]
  - ASIA/G-VII

- Serotype Asia-1:
  - Sindh-08

Table 3-3: Overview of clinical samples collected and tested from Pool 3 in 2019 (countries highlighted in blue; graph represents clinical submissions since 2005)





Laboratory	Countries of Origin	Number of Samples	
		Clinical Field Cases	*Surveillance Activities*
ŞAP Institute, Turkey	Iran, Turkey	147	52314
WRLFMD, UK	Israel, Pakistan, State of Palestine, Saudi Arabia, Turkey	203	0

Pool 3 headlines:

- The FAO, Pakistan Office, Islamabad, Pakistan, National Veterinary Laboratories, Islamabad, Pakistan, Livestock and Dairy Development Department, Government of Punjab, Pakistan together with the WRLFMD have detected the O/ME-SA/Ind-2001e lineage in Pakistan (Hicks et al., 2020: Figure A4.6). This lineage has not previously been identified in Pakistan or in neighbouring countries to the west, i.e., Afghanistan and Iran, except for a single report of O/ME-SA/Ind-2001d in Iran in 2009. The onward spread of O/ME-SA/Ind-2001e needs to be carefully monitored.
- Elsewhere in the region, the O/ME-SA/PanAsia-2^{QOM-15} lineage has caused extensive outbreaks in Israel and Turkey.

Hicks H. M., Wadsworth J., Azhar M., Manzoor S., Abubakar M., Khan E., King D. P. and Knowles N. J. (2020) Genome sequence of foot-and-mouth disease O/ME-SA/Ind-2001e strains isolated in Pakistan. *Microbiology Resource Announcements* 9: e00165-20.

3.3.2 Vaccine recommendations for Pool 3

Internationally produced vaccines

- MSD and Boehringer-Ingelheim (Merial)*:
  - O/ME-SA/PanAsia-2 (or suitable alternative)
  - O/Manisa
  - A Iran-05 (or A TUR 06)
  - A22/Iraq
  - Asia-1 Shamir
  - A/G-VII (from BI)
- Locally produced vaccines (at FGBI ARRIAH):
  - O/PanAsia-2

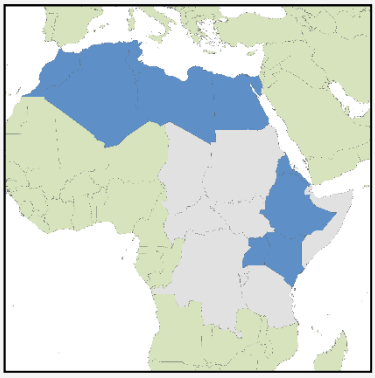
    - A/ASIA/G-VII
    - Asia-1/Sindh-08
    - A/ASIA/Iran-05 (from the Russian isolate /Krasnodarsky/RUS/2013)
- Locally produced vaccines:
    - O/PanAsia-2/QOM-15
    - A05 variant
    - A/Asia/G-VII
    - Asia 1/TUR 15 (Sindh-08)
    - Asia1/Shammir
- Locally produced vaccines (other suppliers in the region):
    - Vetal
    - MEVAC

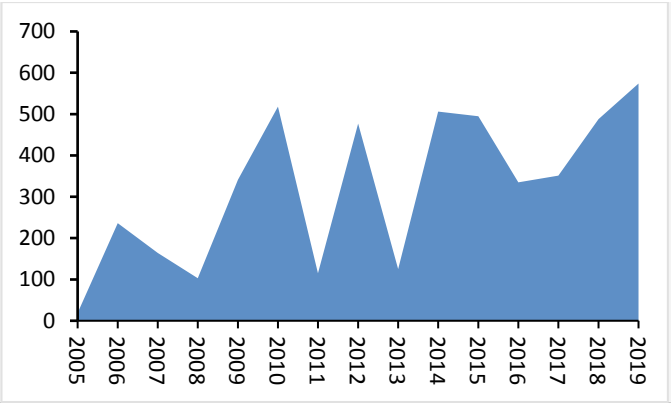
3.4 Pool 4 Regional synopsis

3.4.1 Conjectured circulating FMD viral lineages in Pool 4 during 2019

- Serotype O:
    - EA-2 (Kenya, Tanzania, DR Congo, Uganda)
    - EA-3 (Egypt, Ethiopia, Eritrea, Sudan)
    - EA-4 (Ethiopia, Kenya, Uganda)
    - ME-SA/Sharqia-72 (detected in samples collected in Egypt in 2009)
    - ME-SA/Ind2001 (in Libya, Tunisia, Algeria and Morocco)
- Serotype A
    - AFRICA/I (Kenya, Tanzania, D.R. Congo)
    - AFRICA/IV (Algeria, Sudan, Eritrea, Egypt)
    - AFRICA/VII (Ethiopia, Egypt)
    - ASIA/Iran-05^{BAR-08} (Egypt)
- Serotype SAT 1
    - I (Kenya, Tanzania)
    - IX (Ethiopia)
- Serotype SAT 2:
    - IV (Kenya, Tanzania)
    - VII (Sudan, Egypt, Mauritania)
    - XIII (Ethiopia, Sudan)
- Serotype SAT 3
    - Only detected in African buffalo in the south of the Queen Elizabeth National Park, Uganda in 1970, 1997 and 2013).

Table 3-4: Overview of clinical samples collected and tested from Pool 4 in 2019 (countries highlighted in blue; graph represents clinical submissions since 2005). N.B: These figures include samples collected in countries in North Africa where FMD outbreaks have occurred since 2013.





Laboratory	Countries of Origin	Number of Samples	
		Clinical Field Cases	*Surveillance Activities*
Sciensano, Belgium	Ethiopia	69	1529
NAHDIC, Ethiopia	Ethiopia	76	3124
ANSES, France	Algeria, Comoros, Morocco, Tunisia	31	38
IZSLER, Italy	Algeria, Libya	25	0
FMD Laboratory, Kenya	Kenya	131	3304
OVI, South Africa	Uganda	0	3152
WRLFMD, UK	Algeria, Egypt, Eritrea, Ethiopia, Morocco, Tunisia, Uganda	242	0

Pool 4 headlines and status in 2019:

- Continued outbreaks (during 2018/19) due to O/EA-3 in North Africa (Libya and Morocco) following on from cases due to A/AFRICA/G-IV during 2017. There are now two distinct viral lineages responsible for the cases detected in North West Africa (Maghreb) and North East Africa (Egypt).
- Sequence data has detected a new incursion of the SAT 2/VII lineage into Egypt during 2018 representing viruses most closely related to those collected in Ethiopia (also in 2018; See Figure A4.7).
- New outbreaks of O/EA-2 in central Zambia and Comoros (March 2018) have been caused by two different lineages (15% nt difference). The Comoros FMDV sequences are most closely related to samples collected in Tanzania[1], while the Zambia outbreaks appear to represent a south-westerly movement of this lineage from the Malawi/Tanzania/Zambia border (see Figure A4.8).
- A new initiative launched during late 2019/early 2020 aims to motivate vaccine producers to supply good quality FMD vaccines into the East African market (see: https://agresults.org/projects/fmd-vaccine)

[1]unpublished sequence data kindly provided by Prof. C. Kasanga, Sokoine University of Agriculture, Tanzania

3.4.2 Vaccine recommendations for Pool 4

- Internationally produced vaccines:
  - O/Manisa

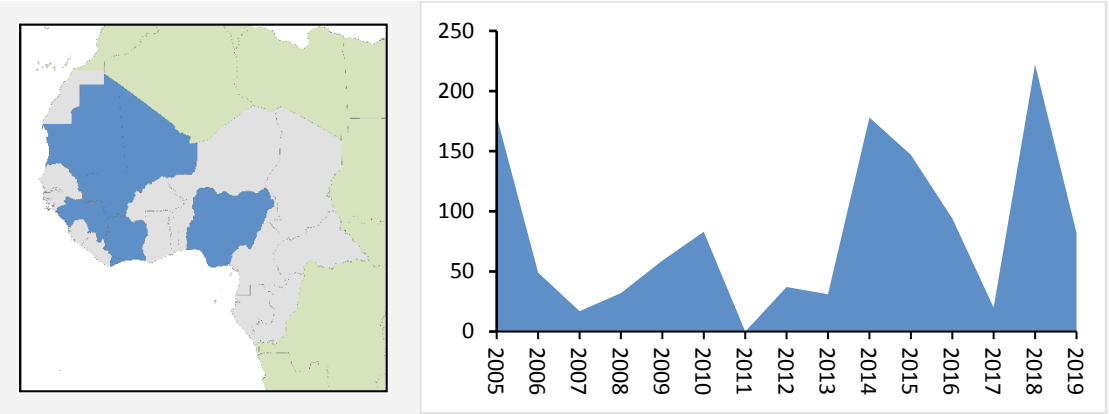
    - O/PanAsia-2 (or equivalent)
    - A/Eritrea (no longer supplied by BI)
    - SAT2/Eritrea
- Locally produced vaccines from KEVIVAPI (Kenya):
    - O: K 77/78 - EA1
    - A: K5/80 - G1
    - SAT1: T155/71 - NWZ
    - SAT2: K52/84 - IV
- Locally produced vaccines from Ethiopia:
    - Serotype O (EA-3)
    - Serotype A (G-IV)
    - Serotype SAT 2 (VII)
- Locally produced vaccines from BVI (Botswana) and ME-VAC (Egypt)

3.5 Pool 5 Regional synopsis

3.5.1 Conjectured circulating FMD viral lineages in Pool 5 during 2019

- Serotype O:
    - WA and EA-3 (Nigeria)
- Serotype A:
    - AFRICA/G-IV & G-VI
- Serotype SAT 1
    - Topotype X (Nigeria and Cameroon)
- Serotype SAT 2:
    - Topotype VII (Mauritania)

Table 3-5: Overview of clinical samples collected and tested from Pool 5 in 2019 (countries highlighted in blue; graph represents clinical submissions since 2005)



Laboratory	Countries of Origin	Number of Samples	
		Clinical Field Cases	*Surveillance Activities*
NCFAD, Canada	Nigeria	28	0
ANSES, France	Côte d'Ivoire, Mali	11	58
NVRI, Nigeria	Nigeria	39	0
WRLFMD, UK	Guinea, Mauritania	4	0

Pool 5 headlines:

- Network laboratories have provided coordinated support to understand the emergence and spread of the O/EA-3 and A/AFRICA/G-IV topotypes in North Africa.
- Collection of good-quality samples from this region remains an important challenge and Network laboratories have implemented novel approaches using nucleic acid recovery from lateral-flow devices as well as RNA transfection methods to characterise FMD viruses causing outbreaks and to fill gaps in surveillance.
- The emergence of O/EA-3 and A/AFRICA/G-IV (in 2017) in the Maghreb is a significant change of epidemiological status which may substantiate new trans-Saharan connections between North and West Africa which raise the onward risks to FMD-free countries in Europe.

3.5.2 Vaccine recommendations for Pool 5

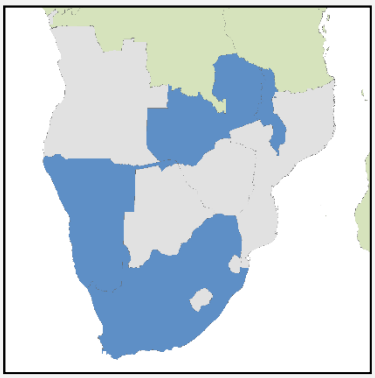
- Internationally produced vaccines:
  - O/Manisa
  - O/Maghreb
  - O/PanAsia-2 (or equivalent)
  - O: 3039
  - A: Eritrea
  - SAT 2: Eritrea & Zimbabwe
- Locally produced vaccines
  - O: NIG 04/14
  - O: WA and EA-3 topotypes
  - A: NIG 07/13
  - A: West Africa (G-IV lineage)
  - SAT 1: Topotype X
  - SAT 2: NIG 03/12
  - SAT 2: Topotype VII
  - O, A, SAT 1 & SAT 2 (Boru-Vacc, Nigeria)

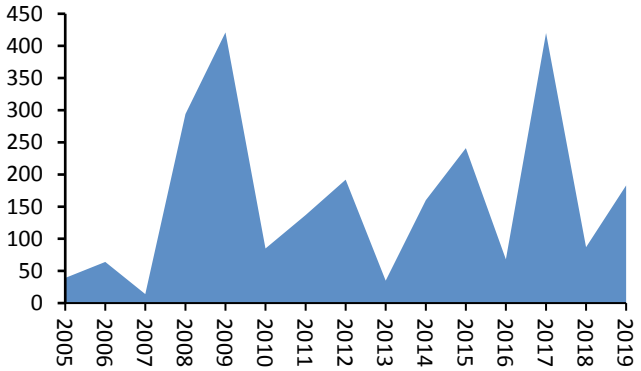
3.6 Pool 6 Regional synopsis

3.6.1 Conjectured circulating FMD viral lineages in pool 6 during 2019

- Serotype SAT 1:
  - Topotypes I, II and III
- Serotype SAT 2:
  - Topotypes I, II and III
- Serotype SAT 3:
  - Topotypes I, II and III)

Table 3-6: Overview of clinical samples collected and tested from Pool 6 in 2019 (countries highlighted in blue; graph represents clinical submissions since 2005)





Laboratory	Countries of Origin	Number of Samples	
		Clinical Field Cases	*Surveillance Activities*
RRLSS, BVI, Botswana	Botswana*, Lesotho, Malawi, Namibia, Zambia	21	1665
ARC-OVI, South Africa	Namibia, South Africa, Zimbabwe	150	65148
WRLFMD, UK	Zambia	12	0

*samples for surveillance only

Pool 6 headlines:

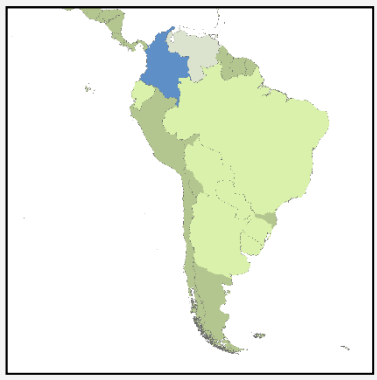
- Sampling of FMD cases in this region has been impacted by the drought in Southern Africa
- There appear to be new risks due to serotype SAT 3 – where recent spread of this serotype may be linked to the drought and movement of animals into new areas
- Outbreaks due to serotype SAT 2 (topotype I) have been reported in South Africa (see Figure A4.9).

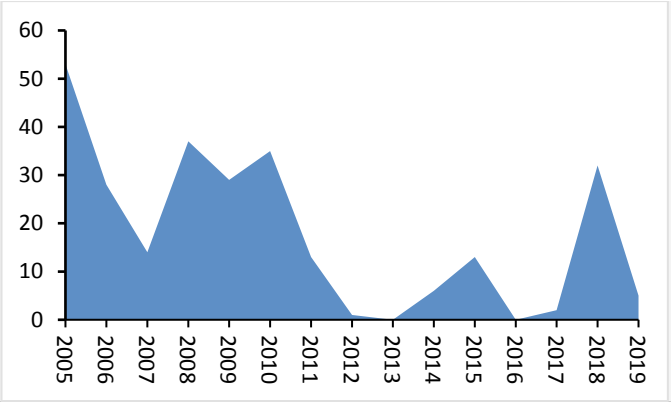
3.6.2 Vaccine recommendations for Pool 6

- Internationally produced vaccines:
  - O: O Manisa
  - SAT 1: SAT105, BVI vaccine
  - SAT 2: SAT251, BVI vaccine
  - SAT 3: SAT306, BVI vaccine
- Locally produced vaccines
  - O: O Manisa
  - SAT 1: SAT105, SAT109, SAR/9/81 (ARC) and a Botswana isolate
  - SAT 2: SAT251, SAT2035, SAR/3/04 (ARC) and KNP/1/10 (ARC)
  - SAT 3: SAT306, SAT309 and KNP/10/90 (ARC)

3.7 Pool 7 Regional synopsis

Table 3-7: Overview of clinical samples collected and tested from Pool 7 in 2019 (countries highlighted in blue; Map background is OIE members official FMD status from June 2020; graph represents clinical submissions since 2005)





Laboratory	Countries of Origin	Number of Samples	
		Clinical Field Cases	*Surveillance Activities*
NCFAD, Canada	Colombia	5	0

Pool 7 headlines:

- Except for Venezuela which has no official FMD status with the OIE, there have been no suspected cases of FMD anywhere in South America during 2019.
- Brazil is expected to suspend vaccination in 2023 (some regions will cease vaccination in 2020)
- A retrospective genetic study has looked at the FMDV isolates from Colombia (O/Euro-SA lineage 6) to highlight a relationship between the viruses of the Andean region (Figure A4.10).

3.7.1 Vaccine recommendations for Pool 7

- Internationally produced vaccines:
  - All vaccines used in the region are produced in South America (Argentina, Brazil, Colombia, Paraguay & Venezuela have vaccine manufacturers)
- Locally produced vaccines
  - O: O_1 Campos
  - A: A_{24} Cruzeiro, A/Arg/2001
  - C: C_3 Indaial *

** will be withdrawn from the vaccine in Brazil, Paraguay and Bolivia in 2019*

4 Improving the quality of laboratory tests from FMD reference laboratories

4.1 Proficiency testing schemes (PTS) organised by the Network Partners

Botswana

- ILC organised
  - 2 international laboratories
  - 10 samples per laboratory

Brazil

- Proficiency testing provided to practice the National Reference Laboratories in the use of molecular and serological tests.
  - 12 countries participated.

Participants from America's National Reference Laboratories		
Total laboratories invited	**Total number of participants**	**Countries**
21	18	Argentina, Brazil, Canada, Chile, Colombia, Ecuador, Mexico, Paraguay, Panama, Peru, Trinidad and Tobago and Uruguay

Proficiency test			
% of labs meeting target performance	**Panels**	**Laboratories**	**Test**
In progress: • Receiving the laboratories results by December 13, 2019 • Panaftosa feedback in April, 2020	1	12	RT-qPCR and RT-PCR typification
	2	12	ELISA typification
	3	17	ELISA-3ABC / EITB
	4	08	ELISA-CFL (LPBE) / virus neutralization

China

- National PT for major animal disease organized by CADC and FMDRL in May 2019
  - funded by MARA
  - FMD and SVA blind samples prepared and provided by FMDRL for real-time RT-PCR test
  - 32 provincial labs were invited.

France

- European Union Proficiency Testing Scheme for FMD

- 37 countries participated from EU and Europe.

Italy

- PTS for Other eastern Mediterranean region laboratory
  - Objective: to evaluate the existing ability of the laboratory to diagnose an FMD outbreak using virological and serological methods
  - Two samples panels sent
    - Panel A for virological tests (real-time RT-PCR &Ag detection ELISA-IZSLER kits). Four epithelium homogenates (some containing an FMDV inactivated virus)
    - Panel B for the Serological test FMDV-NSP-antibody ELISA. Six bovine sera (representative of different FMDV immune-status)
- PTS organised for ten Regional Labs in Italy
  - Panel: 22 sera (naive and various SP-Ab profiles against FMD type O and A)
  - Tests used: IZSLER manufactured kits (SP-ELISA kits and NSP-ELISA kit)
  - Task requested: providing interpretation for each animal

Republic of Korea

- National proficiency tests in South Korea (2019)
  - Regional Diagnostic Centers (9) for FMD antigen and antibody test (twice a year)

Thailand

- Proficiency testing scheme (round 7, 2019)
  - Virus identification byELISA typing test; Antigen detection by RT-PCR; FMD serology byLP ELISA; NSP test.
  - 30 Laboratories:
    - 7 Labs of VRDC [Thailand]
    - 13 Animal quarantinestations (only NSP test) [Thailand]
    - 10 SEA National Labs (2 laboratories in Vietnam and 2 laboratories in Myanmar).
  - PTS being organised: Approved letter sent; Shipment documentation assembled; shipping company contacted.

United Kingdom

	Phase XXXI (2018)		Phase XXXII (2019)*	
Total invited laboratories[1]	94		87	
Total number of shipments[1]	76		2*	
EURL funded participants				
Participants from European Union (funded by EURL for FMD)	26 (EU member states)		To be r	
% of labs meeting target performance[4]	Cat-1 Cat-2 Cat-3 Cat-4	0 % 3.85 % 46.15 % 50 %	Cat-1 Cat-2 Cat-3 Cat-4	- % - % - % - %
EUFMD funded participants				
Participants from Global Network Labs[2]	Argentina, Botswana, Brazil, Canada[3], China, Ethiopia, Kenya, Nigeria Russia, South Africa, Thailand, USA[3].		-	
% of labs meeting target performance[4]	Cat-1 Cat-2 Cat-3 Cat-4	0 % 7.69 % 69.23 % 23.08 %	Cat-1 Cat-2 Cat-3 Cat-4	- % - % - % - %
Participants from EuFMD Member states (non-EU)	Albania, North Macedonia, Norway, Georgia, Serbia, Switzerland, Turkey.		-	
% of labs meeting target performance[4]	Cat-1 Cat-2 Cat-3 Cat-4	0 % 0 % 42.86 % 57.14 %	Cat-1 Cat-2 Cat-3 Cat-4	- % - % - % - %
Participants from neighbourhood countries	Algeria, Armenia, Azerbaijan, Iran, Lebanon, Moldova, Montenegro, Morocco, Tunisia, Egypt, Jordan, Kosovo		-	
% of labs meeting target performance[4]	Cat-1 Cat-2 Cat-3 Cat-4	9.09 % 0 % 63.64 % 27.27 %	Cat-1 Cat-2 Cat-3 Cat-4	- % - % - % - %
Summary of EUFMD funded participants				
Invited	25		-	
Panels shipped	Panel 1	20	Panel 1	-
	Panel 2	20	Panel 2	-
	Panel 3	20	Panel 3	-
	Panel 4	19	Panel 4	-
	Panel 5	6	Panel 5	-
Total number of participants funded by EUFMD	22		-	
Self-funded participants				
Participants	Australia, Namibia, Nepal, New Zealand, Republic of Korea, Senegal, Singapore, Taiwan, UAE		-	
% of labs meeting target performance[4]	Cat-1 Cat-2 Cat-3 Cat-4	0 % 0 % 55.56 % 44.44 %	Cat-1 Cat-2 Cat-3 Cat-4	- % - % - % - %

** At time of writing shipping for the PTS (Phase XXXII) is in progress.*

[1] Additional laboratories (non-NRL) participate in the PTS at their own expense; [2] Not including IZSLER and Sciensano who participate as European NRLs; [3] USA are self-funded; [4] Scored according criteria agreed by the

*NRLs within Europe, each laboratory receives a personalized anonymous feedback letter to highlight areas in which they could improve, and performance of each laboratory is broadly categorized into one of four groups: (**Category 1**) to emphasize critical issues where immediate action is required that impact upon the laboratory to correctly identify FMD virus (virology tests) or FMDV infected animals (serological tests), (**Category 2**) laboratories with serious issues with the performance of individual tests that need to be addressed, (**Category 3**) to record additional observations which may need to be considered by the laboratory to improve the local performance of individual tests and (**Category 4**) laboratories whose tests which are fit for purpose and where no further action is required.*

USA

- Produced and distributed 257 FMD proficiency test (PT) panels and 134 reference/training panels to 47 participating FMD PT National Animal Health Laboratory Network (NAHLN) laboratories.
- Assisted one international laboratory establish an FMD PT program and provided:
    - 3 FMD PT panels
    - 23 FMD controls

4.2 Supply of reagents

Argentina

Type of reagent	Quantity	Recipient of the reagent (Laboratories/Countries)
Hyper immune sera	100	Argentina, Paraguay
3ABC ELISA Reagents	20 sets	Argentina

Belgium

Type of reagent	Quantity	Recipient of the reagent (Laboratories/Countries)
Serum for EU PTS 2019	400 ml	ANSES, France
Serum for EU PTS 2020	600 ml	ANSES, France

Botswana

Type of reagent	Quantity	Recipient of the reagent (Laboratories/Countries)
FMDV antibody kits (RBS and GPS)	150 ml each	CVL, Zimbabwe
FMDV antigen (SAT 1)	150 ml	CVL, Zimbabwe

Brazil

Type of reagent	**Quantity**	**Recipient of the reagent (Laboratories/Countries)**
FMDV Kits for detection of antibodies against nonstructural protein (NSP): *Kit NCP-Panaftosa System (Elisa 3ABC and EITB)*	247	Argentina, Brazil, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela

Type of reagent	Quantity	Recipient of the reagent (Laboratories/Countries)
FMDV Kits for detection of antibodies against structural protein: • Lp-ELISA FMD "O" • Lp-ELISA FMD "A" • Lp-ELISA FMD "C" kits for PVM (post vaccination monitoring) purposes	385	Argentina, Brazil, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela
FMDV antigen kits *FMDV/VSV*	25	Brazil, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela
Positive controls for PCR *BHK-21 and IB RS-II cell lines*	33	Argentina, Colombia
Cell lines	3	Argentina
Antisera (O, A and C)	4	Argentina, Colombia

Canada

Type of reagent	Recipient of the reagent (Laboratories / Countries)
Hybridomas FMDV serotype A monoclonal antibodies	BioStone Animal Health, USA
Hybridomas for monoclonal antibody F1412SA	Tiba Biotech, USA
Hybridomas for monoclonal antibody F1412SA	Merck, USA
Hybridomas for FMD NSP monoclonal antibodies	Kansas State University, USA
Recombinant FMD NSP antigens	PANAFTOSA, Brazil

China

Type of reagent	Quantity	Recipient of the reagent (Laboratories/Countries)
LPBE-O	8160	Veterinary laboratories and large scale breeding companies (China)
LPBE-Asia1	530	
LPBE-A	3150	
NSP-3ABC-ELISA	1643	
SPCE	193	
Conventional Multi-RT-PCR	56	Provincial veterinary laboratories in China
Real-time RT-PCR	918	
Typing real-time RT-PCR	234	

France

Type of reagent	Quantity	Recipient of the reagent (Laboratories/Countries)
Positive control sera (NSP and type O)	4 X 1ml	Regional laboratories in France

India

Type of reagent	Quantity	Recipient of the reagent (Laboratories/Countries)
SPC-ELISA	3,50,000	State FMD Laboratories
DIVA-ELISA	50,000	State FMD Laboratories
Sandwich ELISA	2000	State FMD Laboratories

Italy

2,659 kits supplied to 59 countries:

Kit		Number Supplied
FMDV antigen detection ELISA type O, A, C, Asia1, SAT1-2		253
NSP Ab ELISA KIT (3ABC)		139
SP-Antibody ELISA Kit	FMDV O	1675
	FMDV A	377
	FMDV Asia-1	135
	FMDV SAT 1	24
	FMDV SAT 2	56

Type of reagent	Quantity	Recipient of the reagent (Laboratories/Countries)
BHK-38 suspension cell line	10 vials	Egypt
BHK-21 cell line	2 vials	
Ready-to-use Master Mix for FMDV rtRT-PCR	5 tubes x50 reactions	NRL Algeria
	20 tubes x50 reactions	NRL of 10 Balkan countries

Republic of Korea

Type of reagent	Quantity	Recipient of the reagent
VDRD FMDV 3Diff/PAN Ag Rapid kit	100	Myanmar
RT-PCR kit for Universal	144	
RT-PCR kit for serotype O, A, Asia1	144	
VDpro FMDV NSP Ab ELISA (Median Diagnostic)	1440	
FMDV NSP(3ABC) Antibody ELISA (Bionote)	1440	

Thailand

Type of reagents	Supplied nationally and own lab	Remarks
Rabbit trapping antibody for type O, A and Asia1	Type O = 19 sets Type A = 22 sets Type Asia1 = 15 sets	8 Veterinary Research and Development Centers within Thailand and National Institute of Animal Health (NIAH). Used for antigen and antibody detection
Guinea pig detecting anibody for type O, A and Asia1	Type O = 22 sets Type A = 32 sets Type Asia1 = 19 sets	
Inactivated & concentrated antigen (50X) for type O, A and Asia1	Type O = 41 ml Type A = 41 ml Type Asia1 = 45 ml	
Control serum for C++, C+ and C-	C++ = 185 ml C+ = 140 ml C- = 90 ml	

United Kingdom

Country	Number of vials	Serotype	Reagent type
France	31	A, C, Asia-1 & SAT 1-3	Antigens and Controls
Germany	1	O	Antigen
Iraq	51	O, A, C, Asia-1 & SAT 1-3	Antigens, antisera and controls
Malaysia	32	O, A & Asia-1	Antigens, antisera and controls
South Korea	32	O	Antigens and Controls
Switzerland	12	NSP	NSP
Taiwan	47	O & A	Antisera
UK (internal)	12	O, A, Asia-1 & SAT 2	Antigen, antisera and controls
Vietnam	1159	O, A, C & Asia-1	Antigens, antisera and controls

FMD viruses provided to other FMD labs and commercial companies:

Country	volume	Reagent type
Argentina	21.6 ml	Viral isolate
South Korea	30.6 ml	Viral isolate
Russia	14.4 ml	Viral isolate
Netherlands	5.4 ml	Viral isolate
Commercial companies	122.2 ml	Viral isolate

USA

Type of reagent	Quantity	Recipient of the reagent (Laboratories/Countries)
FMD PT/Reference Panels	47	NAHLN Labs/ U.S.

4.3 Training courses organised by Network partners

Argentina

- Virtual course: *Fiebre aftosa. diagnóstico clínico y de laboratorio. toma, almacenaje y remisión de muestras*.
    - Training in molecular techniques for the detection of the FMD virus.
    - Training in cell culture area
    - Training in biosecurity and biosafety

Belgium

- VP1 sequencing
    - 2 PhD students from Ethiopia

Botswana

- Two staff members from Botswana Institute of Technology Research and Innovation (BITRI) trained on FMD NSPs
- One MSc Student from BUIST on FMDV isolation and RT-PCR

Brazil

- Support Program for the Training of Veterinary Services in the countries to face the last stage of PHEFA (2020-2026) – South America free without vaccination
- VI workshop on differential diagnosis of FMDV – molecular biology
    - 22nd July to 2nd August 2019
    - 12 participants from the National Reference Laboratories of Argentina, Brazil, Colombia, Ecuador, Paraguay and Uruguay.
- Simulation exercise: Foot and mouth disease in Brazil. 4 courses in 2019 - about 50 participants in each training
    - Marabá, Pará, Brazil: for ADEPARA veterinarians of the official service responsible for attending suspected vesicular diseases (11th to 15th March 2019)
    - Ilhéus, Bahia, Brazil: for ADAB veterinarians (8th to 12th April 2019)
    - Vargem Alta, Espirito Santo, Brazil: for IDAF veterinarians (26th to 30th August 2019)
    - Macapá, Amapá, Brazil: for DIAGRO veterinarians (21st to 25th October 2019)

Canada

- Foreign Animal Disease Recognition course (for Canadian veterinarians)
    - Adapted the EuFMD Emergency Preparation Course to reflect Canadian legislation and response to an FMD outbreak.
    - The course was delivered over a 4-week period.
    - 7th May to 7th June 2019.

- Training of CAHSN lab analyst on FMDV RRT-PCR
- FMDV 3ABC ELISA and FMDV RRT-PCR panels provided to the Canadian Animal Health Surveillance Network (CAHSN) laboratories

China

- National training course on FMD diagnostic techniques
- 4 series of Training Courses jointly organized by FMDRL and Diagnosis Center, LVRI.
    - northwest area, southwest area, Jing-Jin-Ji-Jin area and breeding companies
- 8 reports or seminars at workshops organized by provincial labs.
    - Ningxia, Xinjiang, Tibet, Shanxi, Jilin, Qinghai, Chongqing, Anhui
- 3 Biosafety trainings held in LVRI.
- Field training (sampling during active surveillance).

France

- Regional training on FMD epidemiology and diagnostics in response to the incursion of serotype O in West and Central Africa
    - Abidjan
    - 25th to 28th February 2019
- APQA staff trained on Ag-ELISA and LFD
    - At Maisons-Alfort, France
    - 17th to 21st June 2019

India

- ICAR-DFMD organized six-days training programme on 'FMD Post Vaccination Sero-monitoring using Solid Phase Competitive ELISA (SPC-ELISA)' in six batches during October-December 2019.
    - A pool of 43 trained personnel from regional and collaborating centres located in different states was created to undertake the task of sero-monitoring.

Italy

- Laboratory training on cultures and infection of BHK-38 cells in suspension for FMD vaccines production
    - 8th to 21st October 2019
    - three vets from Veterinary Serum and Vaccine Research Institute of Egypt (VSVRI), Ministry of Agriculture
- Biosafety and Biosecurity provisions for BSL-3/4 facilities (Laboratories and Animal housing). In the framework of OIE twinning for "The establishment and development of an OIE collaborating centre on camel diseases"
    - 1st to 11th October 2019
    - two vets from ADFCA, Abu Dhabi (UAE)

Republic of Korea

- Laboratory diagnostic training of regional veterinarians from Regional Diagnostic Centres
    - Total: 3 times
    - 30 Veterinarians

- 7th Workshop on Diagnosis of Animal Diseases
    - 23rd September to 2nd October 2019
    - 12 participants from Mongolia, Malaysia, Kazakhstan and Philippines
        - 8 trained on FMD diagnosis and surveillance, and vaccine evaluation
- KOICA Global Training Program: Surveillance and Diagnosis Development of Foot-and-Mouth Disease in Myanmar
    - Training in Korea by KOICA (Animal and Plant Quarantine Agency)
        - 11th April to 3rd May 2019
        - 7 Participants from LBVD Myanmar (Management level 4, Working level 3)
        - FMD diagnosis and surveillance
    - Training in Myanmar by KOICA (Animal and Plant Quarantine Agency)
        - 23rd June to 7th May 2019
        - 15 Participants from LBVD Myanmar
        - FMD diagnosis and surveillance

Russia

- Seminar: “FMD epidemiology, diagnostics, prevention and control measures”
    - for veterinary specialists of the Republic of Kalmykia (Russia)
    - 19th to 20th March.
- Training in FMD diagnostic methods
    - two specialists from the Republic of Pakistan
    - ARRIAH, 9th to 13th September
- FMD webinar
    - Veterinary students of Moscow Academy of Veterinary Medicine and Biotechnology
    - 4th June
- FMD webinar
    - veterinary specialist from Russia regions
    - 10th October
- Seminar “Actual Issues of Epidemilogy, Diagnostics, Prevention, and Control Measures for African Swine Fever and Foot and Mouth Disease in Modern Conditions”
    - Zabaikalsky kray, Chita, Russia
    - 12th to 13th November

South Africa

- Training on biosafety level-3 (BSL3) facilities and the diagnosis of Transboundary diseases
    - two delegates from the Makerere University, Uganda.
    - Training focused on the operation of a BSL3 laboratory and the diagnosis of FMD and PPR using molecular tests and serology.
- Dr Maree visited APQA, South Korea, during April 2019 to provide training and analysis of sequencing and vaccine matching data.

Thailand

- Dr. Kingkarn Busuya Seeyo, RRLSEA; Training on Monoclonal Preparation of ELISA technique for FMD diagnosis at Exotic Disease Research Station, National Institute of Animal Health (NARO), Kodaira, Tokyo, Japan, 1st May - 30th June 2019.
- Organized IAEA training course on the Use of Nuclear Derived Techniques for Early Detection and Typing of Foot-and-Mouth Disease (FMD) at RRL, Pakchong during 30th September – 25th October 2019 with 4 trainees from Cambodia, Lao PDR, Myanmar and Vietnam. The course was supported by IAEA, Vienna

Turkey

- Training on FMD diagnosis and vaccine QA has been supplied for participants from Azerbaijan and Pakistan
- As a web base online training course on outbreak investigation
    - 250 participants from Turkey
    - technical assistance from EuFMD

United Kingdom

- Training course for diagnostic scientists in East Africa in Sebeta, Ethiopia funded under OIE Twinning Project with NAHDIC, Ethiopia
- Contributed to a training course for West African Scientists organised by the FAO in the Ivory Coast on 25th -28th February 2019
- Scientists from FMD Reference Laboratories and international research institutions participated in e-learning training in FMD diagnostic methods (provided in partnership with EuFMD: https://eufmdlearning.works/).
    - February-March 2019
    - Over 100 scientists, from 55 different countries.
- E-Learning training on post-vaccination monitoring (with summer school) for FMDV
    - More than 30 participants mainly from Southern Africa
- Two-week practical training course covering FMD diagnostic methods during May 2019 for delegates from Oman and New Zealand

USA

- Foreign Animal Disease Diagnostician Training:
    - One week course –8th to 12th April 2019
    - Two week course – 2nd to 14th June 2019
    - One week course – 9th to 13th September 2019
    - One week course – 9th to 13th December 2019

4.4 Collaborative projects

Argentina

Collaborators	Purpose of collaboration	Outcomes
Universidad Nacional de Asuncion, Paraguay (Dr P. Sotelo)	I+D research novel vaccines	Preliminary results
APQA, South Korea (Dr Min Goo Seo)	I+D research evaluation of current in use vaccines	Recently started
INTA (Dr M. Perez Filgueira)	I+D research evaluation of novel vaccines	
Biogenesis BAGO	I+D strain evaluation as vaccine or bang antigen candidates	
Twinning Senasa- Senacsa	Extention of OIE laboratory twinning project between Senasa Argentina and Senacsa Paraguay for improving Senacsa's capacity to perform quality control of FMD vaccines to characterize strains of FMD virus.	Finished

Australia

Collaborators	Purpose of collaboration	Outcomes
• The Pirbright Institute, UK • Wageningen University, Netherlands	Vaccine testing for A/ASIA/GVII against challenge with an A/IRN/05 field strain	• A (high potent) A/ASIA/G-VII vaccine does not protect against A/IRN-05 • Both A/ASIA/G-VII and A/IRN-05 are needed in vaccine banks

Belgium

Collaborators	Collaborative project	Outcomes
NVRI, Nigeria	Bilateral collaboration (follow-up of OIE Laboratory Twinning Program for capacity building)	• Personnel training • Implementation of SOPs • Sample characterisation including phylogenetic analysis
LNV, Burundi	Bilateral collaboration	• Sample characterisation including phylogenetic analysis

Collaborators	Collaborative project	Outcomes
BVI, Botswana	Bilateral collaboration	• Personnel training • Sample characterisation including phylogenetic analysis • Participation of Sciensano in PT organised by BVI
KU Leuven, Belgium	VLIR-UOS project (Initiating a Training Network and Capacity Building to Improve Control of Foot-and-Mouth Disease in Kenya and Ethiopia)	• Personnel training • Sample characterisation including phylogenetic analysis

Botswana

Collaborators	Purpose of collaboration	Outcomes
Botswana Institute of Technology Research and Innovation (BITRI)	Develop and validate a field deployable Lateral Flow Device (LFD) for detection of FMD in the field	LFD device for detecting SATs in the field.

Brazil

Collaborators	Purpose of collaboration	Outcomes
CFIA, Canada	Deep sequence data for South American FMDV isolates	Ongoing study
CFIA, Canada	Development of a test to multiple species for antibodies to FMDVNSP	Ongoing study
CFIA, Canada	Development of a confirmatory test to multiple species for antibodies to FMDV NSP	Ongoing study
CFIA, Canada	Retrospective investigation of anti-SVA neutralizing antibody presence in porcine sera obtained in herds of distinct Brazilian regions	Ongoing study
INIA, Venezuela	Analyse distribution and evolution of VSV strains in Venezuela	Ongoing study

Canada

Collaborators	Purpose of collaboration	Outcomes
PANAFTOSA	Validation of the FMD NSP and enzyme linked immunoblot assay (EITB) for multiple species	An EITB as a confirmatory test for sera from multiple species positive for antibodies to FMDV NSP
PANAFTOSA	Full genome sequencing of archived FMDV isolates in South America	Deep sequence data for South American FMDV isolates
APQA, QIA South Korea	FMD diagnostic kit comparisons and FMD vaccine efficacy studies in cattle	More knowledge on available diagnostic tests and efficacy of FMD vaccines used in South Korea
North American FMD Vaccine Bank	Use of monoclonal antibodies for Vaccine matching and antigenic cartography	Tools for FMD vaccine matching
Iowa State University	Validation of assays for FMDV 3ABC ELISA for antibody detection in swine oral fluids	FMDV 3ABC ELISA for swine oral fluids
National Veterinary Research Institute (NVRI), Nigeria	Capacity building for National and Regional Foot-and-Mouth-Disease Control Strategy (2019 - 2022)	Tools for FMD detection and control
Boerhinger Ingelheim (Merial)	Evaluation of FMD vaccines in pigs	Data on FMD vaccines in pigs
USDA/TetraCore	Validation of FMDV RRT-PCR for swine oral fluids and test method harmonisation	Validated assays for swine oral fluids

China

Collaborators	Purpose of collaboration	Outcomes
Kazakh National Agrarian University, Kazakhstan	Cooperative creation and application studies of new products for prevention and control of major transboundary animal diseases	Constructed the FMD marker vaccines. Established the platform for expression and in vitro assembly of FMD VLPs
National Veterinary Research Institute, Poland	The important animal disease diagnosis platform between China and Poland	Building joint laboratory for animal disease prevention and control under the framework of China-Poland agricultural science and technology center

Collaborators	Purpose of collaboration	Outcomes
Korea Atomic Energy Research Institute	Research and development of FMD viral like particle (VLP)	Immune optimization and mechanism of targeting dendritic cells with FMD VLPs

Ethiopia

Collaborators	Collaborative project	Outcomes
WRLFMD (UK)	OIE twining project	Building the capacity of NAHDIC in different • FMD antigen detection and vaccine matching • Molecular test

France

Collaborators	Purpose of collaboration	Outcomes
SLU	Study of FMDV persistence	- *In vitro* cellular model - Modulation of FMDV persistence
DTU; NRVI; SAP; UM; BI	Field validation of LFD inactivation protocol	Protocol for safe and low-cost shipment of FMD samples

Italy

Collaborators	Purpose of collaboration	Outcomes
The Pirbright Institute, UK	Continuous validation and improvement of diagnostic kits (ELISA), new developments	• Recombinant products (Integrin, VLPs) in ELISA kits • Development of new prototype tests (pan-SP serology, 146S integrity) • Cross-reactivity of SP Ab-ELISAs
University of Turin, Italy	Development of multiplex LFD for FMDV serotyping in field conditions	Two prototypes of LFDs 1. EuroAsian serotypes: O,A,Asia1, pan-FMD 2. SAT 1, SAT 2, pan-SATs
University of Glasgow, UK	To time outbreaks of specific serotypes and inform epidemiological models of disease spread in the context of pastoralist livestock movements in FMD endemic settings	• Profiling of SP-Ab in sera from longitudinal studies • Exploitation of pool 4 topotype-specific real time-PCR

Collaborators	Purpose of collaboration	Outcomes
Maghreb and TransCaucaucasus (TCC) Countries with EuFMD support	Small-scale field trials in Maghreb and TCC countries for the evaluation of vaccine quality and immune responses	Detailed reports of results for three Maghreb trials Sera testing completed for trial in Georgia

Kenya

Collaborators	Purpose of collaboration	Outcomes
• Kenya Wildlife Service • US Department of Agriculture - Plum Island Animal Disease Center • University of Minnesota	Evaluating cross-species transmission of FMD in rangelands shared by buffalo and cattle in Kenya	Improved understanding of FMD transmission dynamics in Kenya

Republic of Korea

Collaborators	Purpose of collaboration	Outcomes
National Center for Veterinary Diagnosis, Department of Animal Health, Hanoi, Vietnam	To carry out comparative studies of Avian influenza virus and Foot and mouth disease virus between Korea and Vietnam	Data and materials (2016-2024)
1. National Animal Health and Production Research Institute, General Directorate of Animal Health and Production, Phnom Penh, Cambodia 2. National Animal Health Laboratory, Ban Sithan Nua, Luang Prabang Rd Km 2., Sikhottabong District, Vientiane Lao PDR	To study on genetic characterization of foot and mouth disease viruses and avian influenza virus in FMD and AI endemic countries (Cambodia and LAO PDR)	Data and materials (2018-2022)
Ministry of Livestock, Fisheries & Rural Development Livestock Breeding and Veterinary Department or other relevant departments, Myanmar	Surveillance and Diagnosis improvement of Foot-and-Mouth Disease in Myanmar (KOICA project)	Professional (Human resources) in FMD diagnosis in Myanmar

- Collaborative network with South Africa
    - Dr. Francois Frederick Maree (OIE Expert, ARC-OVI)
    - To discuss on antigenic evolution of FMD
    - 6th to 13th April 2019
- Collaborative network with Israel
    - Dr. Eyal Klement (Associate professor, Koret School of Veterinary Medicine, Robert H. Smith Faculty of Agriculture, Food and Environment, Israel)
    - To discuss on evaluation of antibody test (SP and NSP Ab) of FMD

- 26th to 30th May 2019

Nigeria

Collaborators	Purpose of collaboration	Outcomes
Sciensano, Belgium	OIE Laboratory Twinning Program for capacity building	• Personnel training • Implementation of SOPs • Sample characterization including phylogenetic analysis
ANSES, France	To evaluate in field conditions of a safe and cost-effective protocol for shipment of samples from FMD suspected cases for laboratory diagnostics	Testing of biosafe transport methods for transport of FMDV RNA to international reference centers
Canadian Food Inspection Agency	Support Foot-and-Mouth-Disease (FMD) Control at country and regional levels through lab capacity building	Hands-on training for technical staff at NVRI, Vom, Nigeria as well as development or improvement of FMD diagnostic tools.

Russia

Collaborators	Purpose of collaboration	Outcomes
Agreement on Transboundary Trade and Mitigation of Transboundary Animal Disease Spread Risk between China, Mongolia and Russia	Cooperation in case of dangerous animal disease emergency, including FMD	Joint FMD control, acquisition of freedom status
CIS Members' Joint Measures to Prevent and Control FMD		
Cooperation on the prevention and control of foot and mouth disease and other transboundary animal diseases between the countries of the Caucasus, Russia and Iran (GF-TADs)	Exchange of information on outbreaks of diseases, vaccination of animals	

South Africa

Collaborators	Purpose of collaboration	Outcomes
The Pirbright Institute (Dr B. Charleston) Oregon State University (Dr A. Jolles)	NSF-EID funded project investigating persistence of FMD in African buffalo. It is a longitudinal study of transmission and antibody dynamics of cohort buffalo over 5 year period in Kruger National Park. Buffalo were also challenged with 3 SAT viruses and transmission traced over time.	Serology dynamics of SAT1, SAT2, SAT3 Deep sequencing of circulating FMD in cohort (Pirbright) Finalization of VI, RT-PCR data The main data was reported in 2017 and 2018.
University of Glasgow (Dr R. Reeve)	Tracking the antigenic evolution of foot-and-mouth disease virus	Genetic basis of antigenic variation of SAT3 viruses. The study has been completed and is currently being written up.
ARS, USDA, USA UVRI, Uganda Makerere University, Uganda TAD, ARC-OVI, South Africa	"Novel countermeasures designed for the progressive control of FMDV in Uganda" To conduct surveillance of FMDV in Uganda and identify the serotype, subtype and genetic makeup of FMDV circulating in Uganda. To carry out serological studies of FMDV circulating in Uganda in support of vaccine matching studies.	Circulation of FMDV was evidenced in 36 districts in Uganda during 2014-2017. High seroprevalence for O (80%) and A (40%), SAT1 and SAT2 (15%) correlates with isolated and sequenced viruses from project. However, exposure to SAT3 was observed in 2 areas (4 herds) even though population seroprevalence is low. Wide distribution of antibodies to 4 serotypes across the country.
Institute of Virology, National Institute of Agricultural Technology (INTA), South America (Drs. M Perez-Filgueira and A Capozzo) The Pirbright Institute, UK (Dr A Ludi) University of Glasgow, UK (Dr R Reeve)	Construction of foot-and-mouth disease (FMD) virus-specific phage-display libraries and epitope identification for improved FMD vaccines generation	Epitope mapping for improved vaccine design

Collaborators	Purpose of collaboration	Outcomes
TIBA, USA Moredun Institute, UK	To evaluate a synthetic modified dendrimer replicon RNA vaccine for cellular and humoral protection against FMD in guinea pigs and cattle (Dosage; Duration; protection).	Vaccine constructs were tested in Guinea pigs at TAD, ARC-OVI. Initial testing of constructs in cattle is underway.
Chitray (TAD, ARC-OVI) NRF funded project (Drs Melanie Chitray, Pamela Opperman, and Francois Maree)	Development of a foot-and-mouth disease virus peptide phage display library for the identification of epitopes recognised by immune sera.	The identification of FMDV epitopes for improved design of recombinant vaccine master seeds virus.
Opperman (TAD, ARC-OVI) NRF funded project (Drs Pamela Opperman, Melanie Chitray and Francois Maree)	Production of FMDV SAT-specific single chain variable fragments (scFvs) for use in diagnostic assays.	Constructed a novel FMD immune phage display library - Inyathi (buffalo) library. The final immune library size is 3.84 x107 cfus. The selected binders will be tested for their use as FMDV diagnostic reagents.
University of Pretoria (Prof Geoff Fosgate)	Epidemiology, Vaccination and Control of FMD in goats at the Greater KNP Area, South Africa.	Commercially available vaccine for small ruminants.
University of Pretoria (Prof Geoff Fosgate)	The development and validation of methods for the diagnosis of foot-and-mouth disease virus (FMDV) infection in goats.	Improved diagnostic assays for small ruminants.
University of Pretoria (Prof Geoff Fosgate)	Evaluation of the solid phase competition ELISA for detecting SAT1 the Foot-and-Mouth Disease virus goats.	Improved diagnostic assays for small ruminants.

Thailand

Collaborators	Purpose of collaboration	Outcomes
• Australian Animal Health Laboratory (AAHL); • OIE-SRR, Bangkok	• Enhancing of laboratory capacity onFMDV diagnosis to develop genotyping using qRT-PCR.	• Develop and enhance the diagnostic techniques and human resource development.

Collaborators	Purpose of collaboration	Outcomes
	• Develop the application of Next Generation Sequencing protocol for whole genome of sequencing of FMD viruses in Southeast Asia. • FMDV vaccine matching study in SEA to determine the antigenic matching of isolated viruses in the region by LP ELISA and VNT.	• Molecular epidemiological information and evolution of FMD in SEA region. • Antigenic variation information of FMDV in the region and selection of appropriate vaccine use in the region.
• National Institute ofAnimal Health (NIAH), Japan o NARO, Tsukuba o Kodaira , Tokyo	• Project: Thailand - Japan Animal Health Research. • Research collaboration on animal diseases. • Organize annual scientific meeting on FMD research between RRL and NIAH Japan. • Organize annual Thailand - Japan Joint Conference on Animal health.	• Sharing knowledge, experiences, technical advances in animal health. • Interchange of researches friendship and cooperation between the two institutes.
• Science and Technology Research Partnership for Sustainable Development (SATREP) o University of Miyazaki, Japan o Japan International o Cooperation Agency (JICA) o Department of Livestock Development (DLD), Thailand	Acceleration of livestock revolution in Thailand aiming at a Kitchen Of The World through development of novel technologies yielding stable livestock production and food safety.	• Rapid diagnosis using qRT-PCR, Next generation sequencing. • To develop multiple diagnosis system (Bovine respiratory disease complex andvesicular diseases). • Fellowship for PhD student.

Turkey

Collaborators	Collaboration project	Outcomes
US	To improve biorisk management	-

United Kingdom

Collaborators	Collaborative project	Outcomes
Malaysian Government	Development of vaccine matching tests for Southeast Asia	Improvement of serological tests for vaccine matching
Iranian Vet Org (Iran) & Embakasi (Kenya)	Validation of RT-PCR methods for milk	Validation of RT-PCR methods for milk

Collaborators	Collaborative project	Outcomes
IZSLER (Italy), ANSES (France) & Lelystad (The Netherlands)	Validation of NSP tests	Inter-laboratory exercise for NSP assays
IZSLER (Italy)	Development of FMD ELISA	New ELISAs for FMD diagnosis
SUA (Tanzania) &TVLA (Tanzania)	Improved tools for the surveillance and diagnosis of FMD	Understanding the epidemiology of FMD in endemic settings
NAHDIC (Ethiopia)	OIE Twinning Project	Improved diagnostic capacity for Ethiopia
INTA (Argentina)	Development of new vaccine matching tests for FMD	Generate validation data for field tests
AU-PANVAC	OIE Twinning Project	Vaccine QA/QC for Africa

USA

Collaborators	Collaborative project	Outcomes
U.S. Department of Homeland Security	Evaluation of a trivalent FMDV serotype A vaccine for pan-A serotype efficacy in cattle	In progress
U.S. Department of Homeland Security	Evaluation of a trivalent FMDV vaccine for homologous protection in swine	In progress
Kansas State University (KSU)	Development of multiplex RT-qPCR assays for detection and differentiation of SVV and FMDV.	Completed and published
Canadian Food Inspection Agency (CFIA)	Method harmonization and evaluating pooling of samples from animals infected with FMDV, CSFV, ASFV; small scale positive cohort evaluation	In progress. Preliminary results from small scale study; additional work is ongoing.

Collaborators	Collaborative project	Outcomes
Canadian Food Inspection Agency (CFIA)	Method harmonization and evaluating oral fluids as a sample for FMDV, CSFV, ASFV; small scale positive cohort evaluation	Promising preliminary results from small scale study; additional work needed; larger scale study to take place at PIADC in spring 2020. Collaboration with industry to collect oral fluid samples from endemic countries. (Necessary for full validation)
U.S. Department of Homeland Security	FMDv cELISA Comparison Project between Prionics 3ABC and VMRD 3B	In progress. Ongoing testing of negative sera samples from Diagnostic Services and the North American Foot and Mouth Disease Vaccine Bank.

Appendix 1 - Details of clinical samples from field cases from countries in FMDV endemic regions tested during 2019

Laboratory	Samples from	Total	O	A	C	Asia 1	Sat 1	Sat 2	Sat 3	Untyped	NVD	Comments
ANSES	Algeria	9	9	-	-	-	-	-	-	-	-	
	Comoros	5	4	-	-	-	-	-	-	-	1	
	Côte d'Ivoire	9	3	-	-	-	-	-	-	6	-	
	Mali	2	2	-	-	-	-	-	-	-	-	
	Morocco	8	7	-	-	-	-	-	-	-	1	
	Tunisia	9	6	-	-	-	-	-	-	2	1	
APQA	Republic of Korea	3	3	-	-	-	-	-	-	-	-	
BVI	Malawi	2	-	-	-	-	-	1	-	-	1	
	Namibia	11	-	-	-	-	-	-	11	-	-	
	Zambia	8	6	-	-	-	-	-	-	-	2	
CSIRO	-	-	-	-	-	-	-	-	-	-	-	
FADDL	-	-	-	-	-	-	-	-	-	-	-	
FGBI ARRIAH	Russia	28	15	-	-	-	-	-	-	-	13	
FMD laboratory, Kenya	Kenya	131	14	5	-	-	42	25	-	-	45	
ICAR-DFMD	India	306	145	2	-	-	-	-	-	-	159	
IZSLER	Algeria	9	9	-	-	-	-	-	-	-	-	
	Libya	16	7	-	-	-	-	-	-	-	9	
LVRI	China	76	21	2	-	-	-	-	-	3	50	
NAHDIC	Ethiopia	76	35	20	-	-	-	5	-	-	16	
NCFAD	Colombia	5	5	-	-	-	-	-	-	-	-	
	Nigeria	28	8	-	-	-	-	8	-	12	-	
NVRI	Nigeria	39	3	12	-	-	-	1	-	2	21	
ARC - OVI	South Africa	150	-	-	-	-	-	24	-	-	126	
PANAFTOSA	-	-	-	-	-	-	-	-	-	-	-	
ICAR - DFMD	-	-	-	-	-	-	-	-	-	-	-	No data reported
RRLSEA	Thailand	118	26	47	-	-	-	-	-	28	17	
ŞAP Institute	Turkey	127	68	-	-	-	-	-	-	6	53	
Sciensano	Ethiopia	69	3	6	-	-	-	-	-	37	23	
	Luxembourg	6	-	-	-	-	-	-	-	-	6	
SENASA	Argentina	9	-	-	-	-	-	-	-	-	9	
WRLFMD	Algeria	11	8	1	-	-	-	-	-	1	2	1 sample dually positive for O and A
	Bhutan	34	21	-	-	-	-	-	-	9	4	
	Egypt	36	1	1	-	-	-	6	-	19	9	
	Eritrea	47	6	1	-	-	-	15	-	16	9	
	Ethiopia	90	23	38	-	-	-	-	-	9	21	1 sample dually positive for O and A
	Guinea	3	3	-	-	-	-	-	-	-	-	
	Hong Kong, SAR of PRC	13	9	-	-	-	-	-	-	2	2	
	Israel	111	92	-	-	-	-	-	-	8	11	
	Mauritania	1	1	-	-	-	-	-	-	-	-	
	Mongolia	7	6	-	-	-	-	-	-	-	1	
	Morocco	4	4	-	-	-	-	-	-	-	-	
	Myanmar	15	2	-	-	-	-	-	-	10	3	

Laboratory	Samples from	Total	O	A	C	Asia 1	Sat 1	Sat 2	Sat 3	Untyped	NVD	Comments
	Nepal	50	44	-	-	-	-	-	-	5	1	
	Pakistan	36	10	2	-	19	-	-	-	4	1	
	Palestine, State of	5	3	-	-	-	-	-	-	-	2	
	Republic of Korea	5	5	-	-	-	-	-	-	-	-	
	Saudi Arabia	11	6	-	-	-	-	-	-	2	3	
	Thailand	20	4	16	-	-	-	-	-	-	-	
	Tunisia	2	2	-	-	-	-	-	-	-	-	
	Turkey	40	20	8	-	-	-	-	-	6	6	
	Uganda	52	8	4	-	-	-	-	-	3	37	
	Vietnam	55	47	-	-	-	-	-	-	5	3	
	Zambia	12	6	-	-	-	-	4	-	-	2	

Appendix 2 - Vaccine matching studies undertaken by Network partners during 2019

Vaccine efficacy is influenced by both vaccine potency and vaccine match and it is possible that a poor match may to some extent be compensated by high potency vaccines and by administering more than one dose at suitable intervals. The use of oil adjuvant is also expected to improve efficacy. Thus, a vaccine with a weak antigenic match to a field isolate, as determined by serology, may nevertheless afford some protection if it is of sufficiently high potency. Therefore, in the absence of a good match, or where the match is unknown, vaccines of high potency should preferably be used. The r_1 values shown below, represent the one way serological match between vaccine strain and field isolate, calculated from the comparative reactivity of an antiserum, raised against the vaccine in question, to the vaccine virus and the field isolate.

Key:

M	Matched with the vaccine
B	Borderline
N	Not matched with the vaccine

For VNT:

$r_1 \geq 0.3$ – suggest that there is a close relationship between field isolate and vaccine strain. A potent vaccine containing the vaccine strain is likely to confer protection

$r_1 \leq 0.3$ - suggest that the field isolate is so different from the vaccine strain that the vaccine is unlikely to protect.

For LB-ELISA:

$r_1 \geq 0.4$ – suggest that there is a close relationship between field isolate and vaccine strain. A potent vaccine containing the vaccine strain is likely to confer protection

$r_1 \leq 0.4$ - suggest that the field isolate is so different from the vaccine strain that the vaccine is unlikely to protect.

Argentina

- Total of determinations 4261 for vaccine matching r1 value assessment and for neutralizing antibody titres.
- Serotype O lineages: O/ME-SA/PanAsia, O/SEA/Mya-98, O/ME-SA/Ind-2001, O/CATHAY, O/ME-SA/PanAsia-2, O/EURO SA
- Serotype A lineages: A/ASIA/Sea-97, A/EURO SA

Botswana

	R_1 value per Vaccine virus strain SAT 251	SAT 306	SAT 309
SAT 3/NAM		0.78	0.39
SAT 2/ZIM	0.61		

Brazil

- DPV (Days post vaccination)
- DPR (Days post revaccination)
- VNT: using suspension IBRS-2 cell line and reference panel BVS OL-491:

Field isolate				**Vaccine Strain O_1 Campos**	
Sample identification	**Serotype; Topotype; Lineage** (Andean region of South America)			**r_1 30 DPV**	**r_1 30 DPR**
O/Sogamoso-Boyaca/Colombia/2018 LREF 157.826	O	EURO-SA	Andean 2018 6	0.46	1.16
O/Maycao-Guajira/Colombia/2018 LREF 157.876	O	EURO-SA	Andean 2018 6	0.63	0.96
O/San_Diego-Cesar/Colombia/2018 LREF 157.878	O	EURO-SA	Andean 2018 6	0.52	0.91

Virus identification	**Serotype; Topotype; Lineage** (Andean region of South America)			**EPP 30 DPV**	**EPP 30 DPR**
O/Sogamoso-Boyaca/Colombia/2018 LREF 157.826	O	EURO-SA	Andean 2018 6	87.37 %	99.56 %
O/Maycao-Guajira/Colombia/2018 LREF 157.876	O	EURO-SA	Andean 2018 6	92.37 %	99.60 %
O/San_Diego-Cesar/Colombia/2018 LREF 157.878	O	EURO-SA	Andean 2018 6	88.06 %	98.97 %
O1 Campos Br/58 (Vaccine master-seed virus)	O	EURO-SA	Vaccine virus Reference (Lineage 5)	96.93 %	99.88 %

China

Field isolate	lineage	animal	Vaccine strain tested against	Result
19025	A/Sea-97	cattle	Re-A/WH/09	M

Field isolate	lineage	animal	Vaccine strain tested against	Result
18074	O/CATHAY	pig	O/BY/2010	N
19011	O/Ind-2001	cattle	O/BY/2010	M
19028	O/CATHAY	pig	O/BY/2010	N

Ethiopia

Field Isolate	Vaccine strain					
	O/3039	O/Manisa	O/TUR/5/2009	A/Iran 2005	A/TUR20/06	A22/IRQ/24/64
O/ETH/73/2018	0.5	0.29	1			
O/ETH/9/2019	0.76	0.52	0.71			
A/ETH/85/2018				0.05	0	0
A/ETH/19/2019				0.05	0	0

* Vaccine matching completed at WRLFMD

India

- A total of 9 virus isolates were subjected to vaccine matching exercise using bovine vaccinate serum.
    - The isolates were sampled from different states and different time point.
    - All the 9 isolates had an r_1-value of >0.3 with currently used serotype O vaccine strain INDR2/1975, which indicates optimal antigenic coverage by the in-use vaccine strain.

Republic of Korea

VNT	Type O Vaccine strains			
	O1 Manisa	O 3039	O Primorsky 14	O1 Campos
O/SKR/1/2019	0.54	0.36	0.33	0.34

Russia

Isolate	O TWN/ 97	Russia PanAsia/ 2000	Russia PanAsia/ 2012	PanAsia2	Russia SEA/ 2010	Russia SEA/ 2014
O/Primorsky/2019	ND	0.19	0.1	0.29	ND	0.99
O/Zabaikalsky/2019	0.11	ND	0.23	0.99	0.78	0.44

Thailand

Country/ topotype	No. of Sample	r-value by LP ELISA Serotype O/Thai Vaccine Strain O/189/87		
		≤ 0. 19	0.2-0.39	≥ 0.4
Thailand O/ME-SA/Ind2001e	11	-	-	11

Country/ topotype	No. of Sample	r-value by LP ELISA Serotype A/Thai Vaccine Strain A/Sakolnakorn/97			A/Lopburi/2012		
		≤ 0. 19	0.2 - 0.39	≥ 0.4	≤ 0.19	0.2 - 0.39	≥ 0.4
Thailand A/Asia/Sea-97	33*	1	1	10	2	-	31

* 21 of 33 field isolated samples in 2019 indicated no binding reaction to A/Sakolnakorn/97 in the antigen titration step, therefore vaccine matching tests could not be done for these samples

Turkey

	Vaccine strain	
	OTUR07	OTUR17 (QOM-15)
O/TUR/7/2019 (O/PAII/QOM-15)	0.38	0.42
O/TUR/11/2019 (O/PAII/QOM-15)	0.85	0.24

	Vaccine strain	
	Asia1 TUR15	Asia1 Shamir
IRN 98/20 (Asia 1/Sindh-08)	0.62	0.095

	Vaccine strain	
	A TUR 06	A IRN 17
IRN 98/1 (A/ASIA/Iran-05)	0.22	0.77

United Kingdom

Note:

N	No Match ($r_1 \leq 0.28$)
B	Borderline (r_1 is between 0.28 and 0.32)
M	Match ($r_1 \geq 0.32$)

Serotype	Topotype	Lineage	Strain	O 3039	O1 Manisa	O/TUR/5/2009	O 5911	O SKR 7/10
O	CATHAY	-	HKN/21/2018	0.2	0.09	0.13	NT	NT
			HKN/23/2018	0.2	0.11	0.09	NT	NT
			HKN/01/2019	0.2	0.12	0.16	NT	NT
			HKN/04/2019	0.2	0.08	0.09	NT	NT
			VIT/06/2018	0.1	0.08	0.13	NT	NT
O	EA-2	-	UGA/06/2019	0.6	0.31	0.68	NT	NT
			UGA/10/2019	0.1	0.09	0.28	NT	NT
			UGA/21/2019	0.6	0.32	0.66	NT	NT
			ZAM/02/2019	0.6	0.31	0.44	NT	NT
O	EA-3	-	ALG/05/2018	0.9	0.51	0.62	NT	NT
			ALG/11/2018	0.8	0.58	0.81	NT	NT
			ALG/01/2019	0.5	0.33	0.52	NT	NT
			BKF/04/2018	1	0.87	0.93	NT	NT
			BKF/09/2018	0.7	0.66	0.68	NT	NT
			CIV/03/2018	0.6	0.46	0.76	NT	NT
			EGY/34/2017	0.7	0.47	0.5	NT	NT
			ETH/20/2018	0.4	0.46	0.36	NT	NT
			ETH/23/2018	0.5	0.56	0.56	NT	NT
			ETH/73/2018	0.5	0.29	1	NT	NT
			ETH/09/2019	0.8	0.52	0.71	NT	NT
			GNA/03/2018	0.6	0.4	0.5	NT	NT
			MAU/01/2018	0.8	0.22	0.47	NT	NT
			MOR/01/2019	0.6	0.48	0.87	NT	NT
			PAT/01/2018	0.7	0.46	0.56	NT	NT
			SEL/13/2018	0.8	0.58	0.28	NT	NT
			SSD/06/2017	0.8	0.93	0.72	NT	NT
			TUN/01/2019	0.5	0.46	0.47	NT	NT
O	ME-SA	Ind-2001	MOG/21/2018	0.4	0.45	0.56	NT	NT
			MOG/23/2018	0.5	0.4	0.76	NT	NT
			NEP/07/2018	0.4	0.4	0.89	NT	NT
			NEP/01/2019	0.7	0.38	0.85	NT	NT
			PAK/01/2019	0.8	0.59	0.69	NT	NT
			SKR/01/2019	0.6	0.45	0.85	NT	0.69
			SKR/04/2019	0.7	0.52	0.78	NT	0.74
			TAI/13/2017	0.4	0.35	0.51	NT	NT
			TAI/16/2017	0.3	0.28	0.28	NT	NT

Serotype	Topotype	Lineage	Strain	O 3039	O1 Manisa	O/TUR/5/2009	O 5911	O SKR 7/10
			TAI/15/2018	1	0.72	1	NT	NT
O	ME-SA	Ind-2001e	BHU/01/2019	0.4	0.49	0.49	NT	NT
			BHU/09/2019	0.4	0.34	0.47	NT	NT
			SAU/08/2018	0.4	0.71	0.4	NT	NT
			SAU/11/2018	0.4	0.62	0.54	NT	NT
O	ME-SA	PanAsia	LAO/01/2018	0.8	0.93	0.69	NT	NT
			TAI/04/2018	0.5	0.45	0.38	NT	NT
			VIT/10/2018	0.3	0.38	0.56	NT	NT
O	ME-SA	PanAsia-2	ISR/02/2018	0.3	0.3	0.48	0.4	NT
			ISR/04/2018	0.2	0.24	0.5	0.4	NT
			ISR/42/2018	0.4	0.39	0.46	NT	NT
			ISR/71/2018	0.7	0.6	0.69	NT	NT
			ISR/78/2018	0.7	0.65	0.69	NT	NT
			ISR/12/2019	0.7	0.39	0.47	NT	NT
			ISR/27/2019	0.6	0.44	0.5	NT	NT
			PAK/12/2019	0.7	0.5	0.76	NT	NT
			PAK/23/2019	0.8	0.45	0.51	NT	NT
			PAT/03/2019	0.5	0.27	0.58	NT	NT
			PAT/04/2019	0.8	0.36	0.56	NT	NT
			TUR/11/2018	0.7	0.35	0.79	NT	NT
			TUR/04/2019	0.7	0.35	0.79	NT	NT
O	SEA	Mya-98	MOG/25/2018	0.6	0.22	0.47	NT	NT
			MYA/01/2013	0.6	0.29	0.68	NT	NT
			TAI/14/2018	0.4	0.27	0.29	NT	NT
			VIT/01/2019	0.3	0.24	0.3	NT	NT

Serotype	Topotype	Lineage	Strain	A/IRN/05	A/TUR/20/06	A22 IRAQ	A/ERI/3/98	A MAY 97	A/ASIA/GVII
A	AFRICA	G-I	UGA/28/2019	0.05	0.15	0.14	0.15	NT	0
			UGA/42/2019	0.06	0.17	0.17	0.28	NT	0
			ZAM/4/2018	0.45	0	0.43	0.17	NT	NT
			ZAM/5/2018	0.5	0	0.5	0.19	NT	NT
A	AFRICA	G-IV	EGY/2/2018	0.03	0.11	0.12	0.42	0	NT
			ETH/35/2018	0.04	0	0.09	0.25	0	NT
			ETH/48/2018	0.04	0	0.17	0.21	0	NT
			ETH/85/2018	0.05	0	0	NT	NT	NT
			ETH/19/2019	0.05	0	0	NT	NT	NT
A	ASIA	G-VII	TUR/01/2017	0	0	0.15	NT	NT	0.85
			TUR/13/2017	0	0	0.17	NT	NT	0.78

Serotype	Topotype	Lineage	Strain	A/IRN/05	A/TUR/20/06	A22 IRAQ	A/ERI/3/98	A MAY 97	A/ASIA/GVII
A	ASIA	Iran-05	PAK/01/2018	0.36	0.25	0.32	NT	NT	0
			PAK/24/2019	0.49	0.59	0.48	NT	NT	0
A	ASIA	Sea-97	TAI/10/2017	0.09	0	0.41	NT	0.34	NT
			TAI/19/2017	0.07	0	0.46	NT	0.28	NT
			TAI/7/2019	0.35	0	0.43	NT	0.21	NT
			TAI/8/2019	0.32	0	0.51	NT	0.2	NT

Serotype	Topotype	Lineage	Strain	Asia-1 Shamir
Asia-1	ASIA	Sindh-08	PAK/10/2019	0.4
			PAK/11/2019	0.4
			PAK/14/2019	0.3

Serotype	Topotype	Lineage	Strain	SAT 2 ERI	SAT 2 ZIM
SAT 2	I	-	ZAM/10/2019	0.7	0.4
			ZAM/12/2019	0.7	0.2
SAT 2	VII	Ghb-12	EGY/1/2018	0.3	0.1

Appendix 3 - Nucleotide sequence analysis

FMDV nucleotide sequence data for phylogenetic analysis

Testing Laboratory	Submitting country	Region sequenced	Total	O	A	Asia-1	SAT 1	SAT 2	SAT 3	FMDV GD	Notes
SENASA	Argentina	VP1	27	16	11						
	Vietnam	VP1	26	26							
Sciensano	Ethiopia	VP1	9	3	6						
BVI	Malawi	VP1	1					1			
	Namibia	VP1	11						11		
	Zambia	VP1	6	6							
PANAFTOSA	Colombia	Complete Genome	5	5							
	Colombia	VP1	7	7							
NCFAD	Nigeria	Complete Genome	28	8				8			
	Nigeria	VP1	28	10				8			Next Generation Sequencing sequencing of unknown serotype samples
	Nigeria	VP1	2	2							
	Colombia	VP1	5	5							
	Colombia	Complete Genome	5	5							
LVRI	China	VP1	67	65	2						
ANSES	Mali	VP1	2	2							
	Comoros	VP1	4	4							
	Tunisia	VP1	6	6							
	Tunisia	Complete Genome	2	2							
	Morocco	VP1	6	6							
	Morocco	Complete Genome	4	4							
	Algeria	VP1	9	9							
	Algeria	Complete Genome	3	3							
	Côte d'Ivoire	VP1	3	3							
	Côte d'Ivoire	Complete Genome	3	3							
IZSLER	Algeria	VP1	6	6							
	Libya	VP1	1	1							
QIA	Republic of Korea	VP1	3	3							
	Republic of Korea	Capsid	3	3							
	Republic of Korea	Complete Genome	3	3							

Şap Institute	Turkey	VP1	34	34						
	Iran	VP1	20	6	5	9				
RRLSEA	Thailand	VP1	60	17	43					
FGI ARRIAH	Russia	VP1	41	41						
OVI	South Africa	VP1	15					15		
WRLFMD	Algeria	VP1	8	8						
	Bhutan	VP1	21	21						
	Côte d'Ivoire	VP1	3	3						
	Egypt	VP1	8	1	1			6		
	Eritrea	VP1	22	6	1			15		
	Ethiopia	VP1	61	23	38					
	Guinea	VP1	3	3						
	Hong Kong	VP1	10	10						
	Israel	VP1	93	93						
	Republic of Korea	VP1	5	5						
	Mauritania	VP1	1	1						
	Mongolia	VP1	6	6						
	Morocco	VP1	4	4						
	Myanmar	VP1	2	2						
	Nepal	VP1	44	44						
	Pakistan	VP1	12	10	2					
	Palestine, state of	VP1	3	3						
	Saudi Arabia	VP1	6	6						
	Thailand	VP1	20	4	16					
	Tunisia	VP1	2	2						
	Turkey	VP1	28	20	8					
	Uganda	VP1	12	8	4					
	Vietnam	VP1	47	47						
	Zambia	VP1	10	6				4		
TOTALS		**VP1**	**830**	**614**	**137**	**9**	**-**	**49**	**11**	**-**
		Capsid	**3**	**3**	**-**	**-**	**-**	**-**	**-**	**-**
		Complete Genome	**53**	**33**	**-**	**-**	**-**	**8**	**-**	**-**
		All	**886**	**650**	**137**	**9**	**-**	**57**	**11**	**-**

Appendix 4 - Selected phylogenetic trees for 2019

Figure A4.1: Serotype O - China

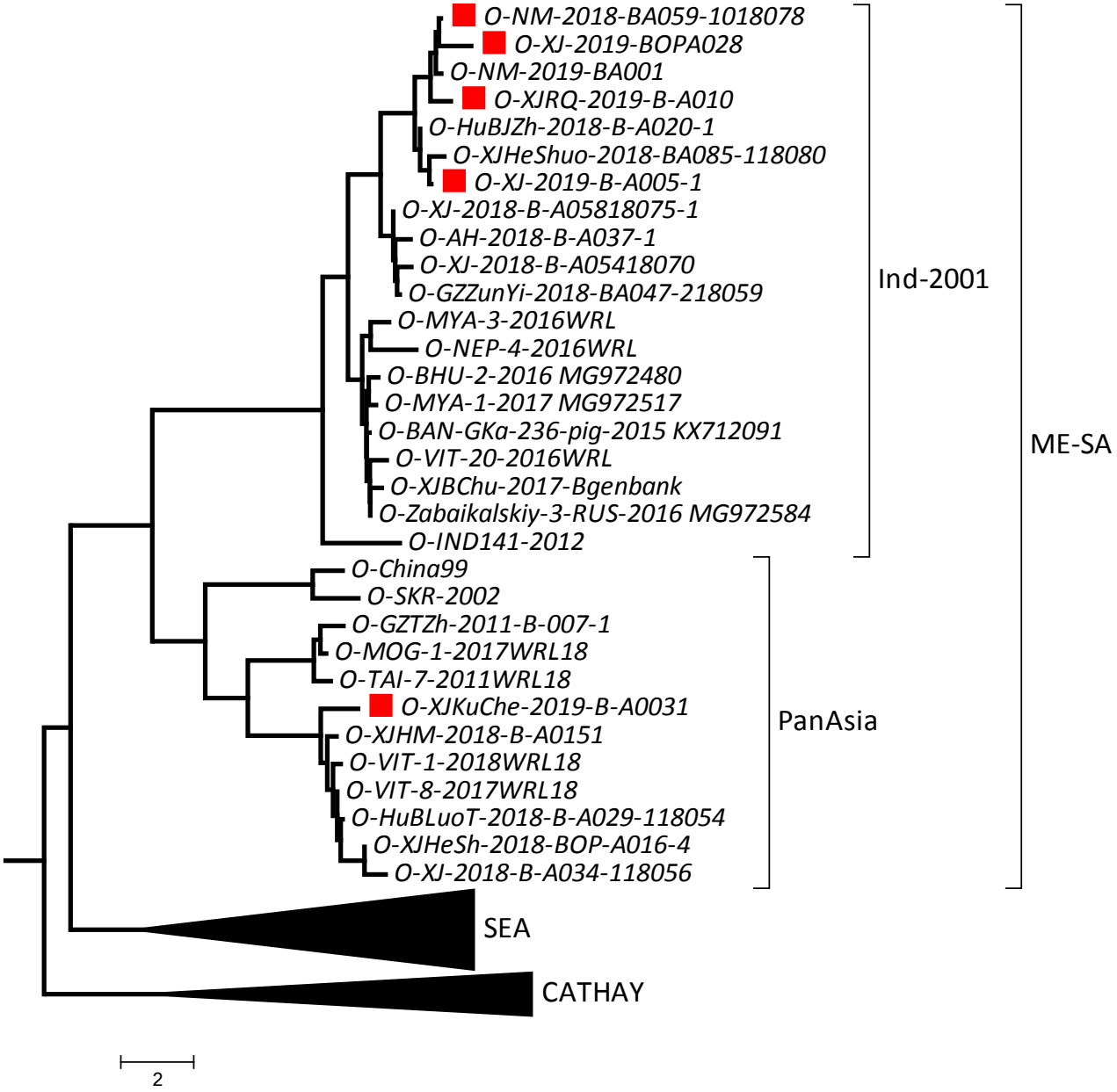


Figure A4.2: Serotype A: China

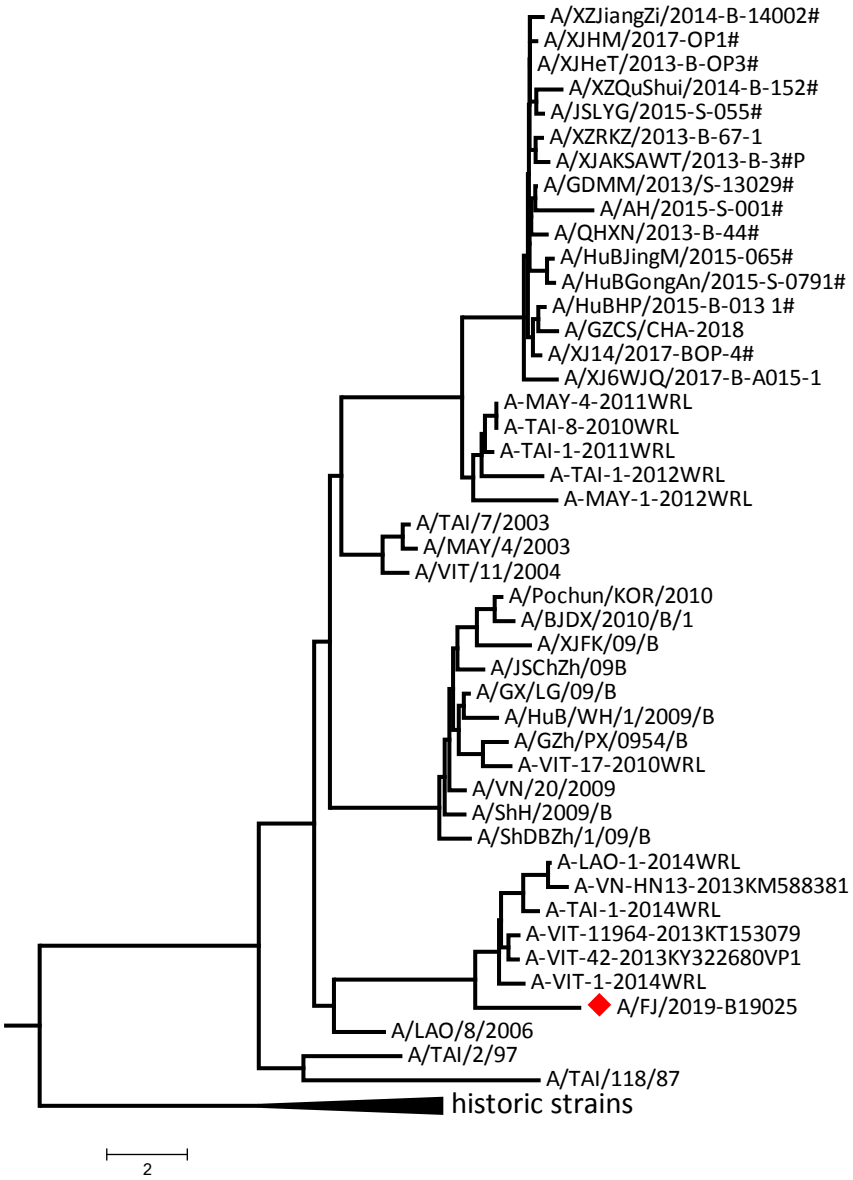


Figure A4.3: O/ME-SA/Ind-2001 in The Republic of Korea

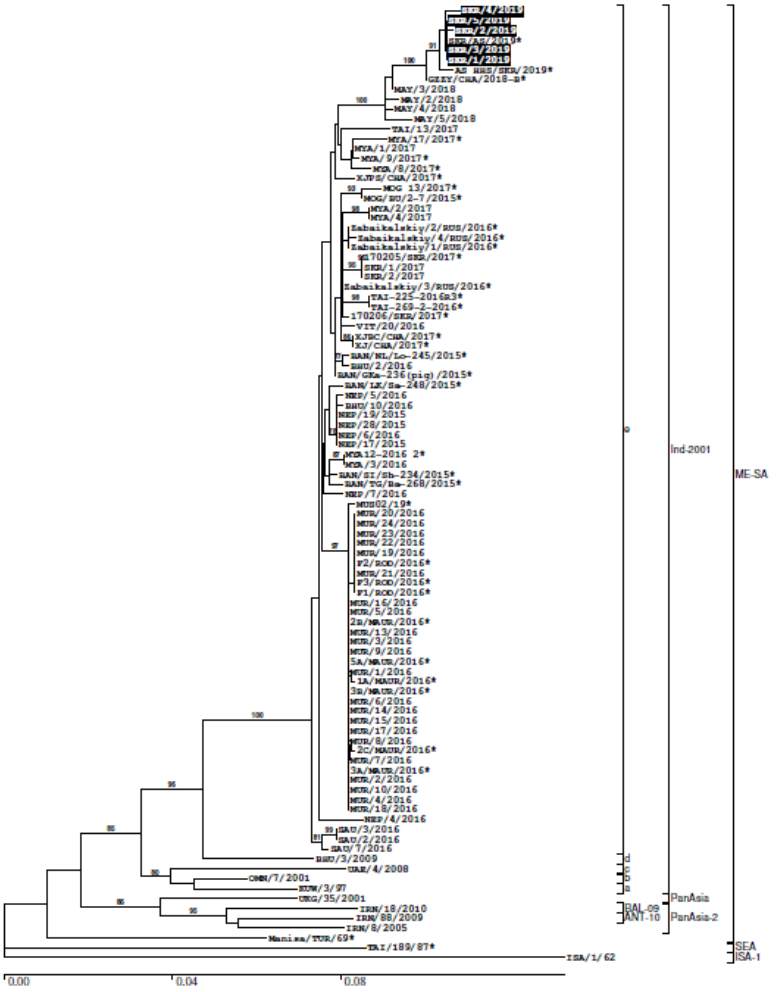


Figure A4.4: O/SEA/Mya-98 in Russia

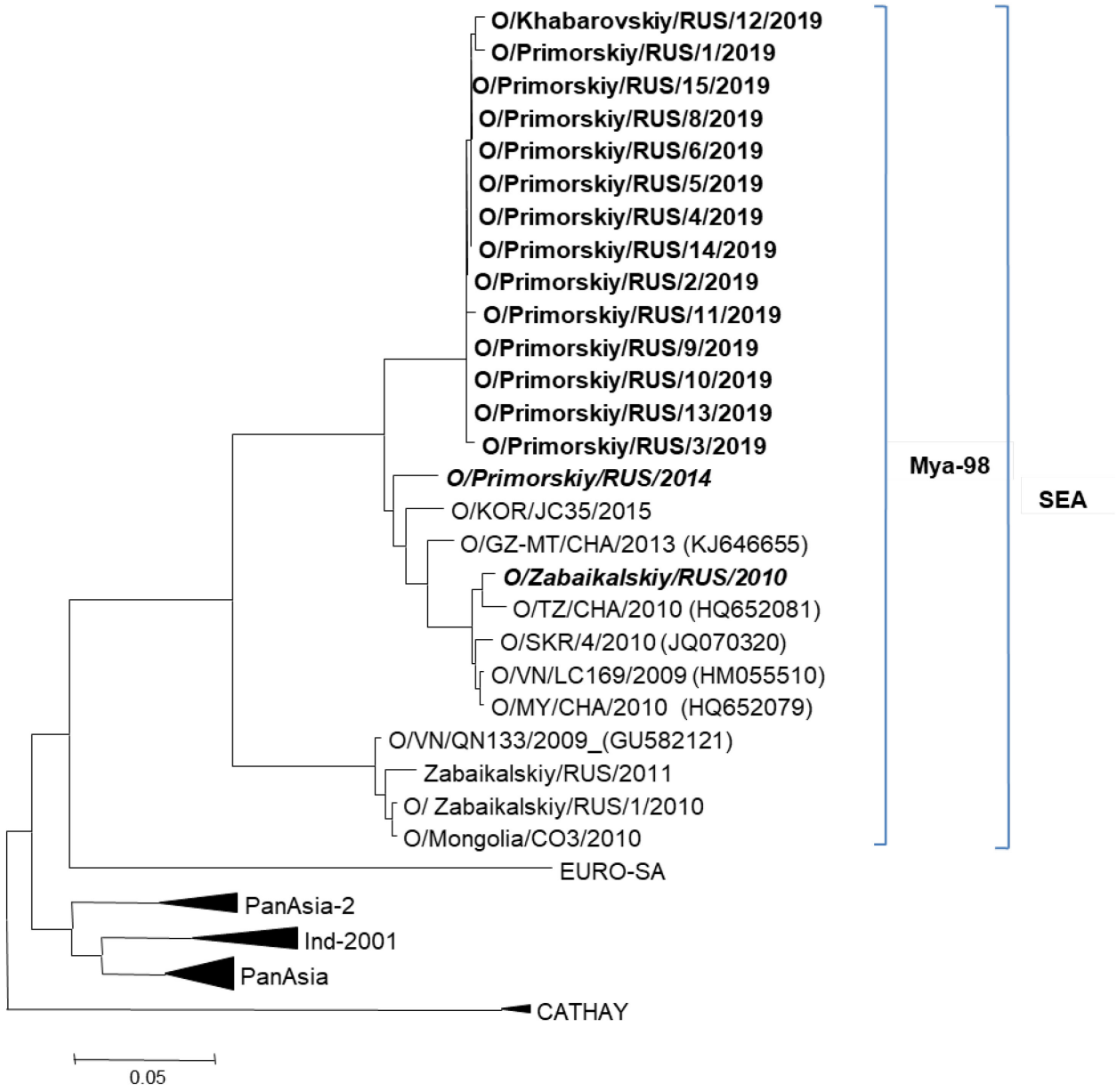


Figure A4.5: O/ME-SA/Ind-2001 in Russia

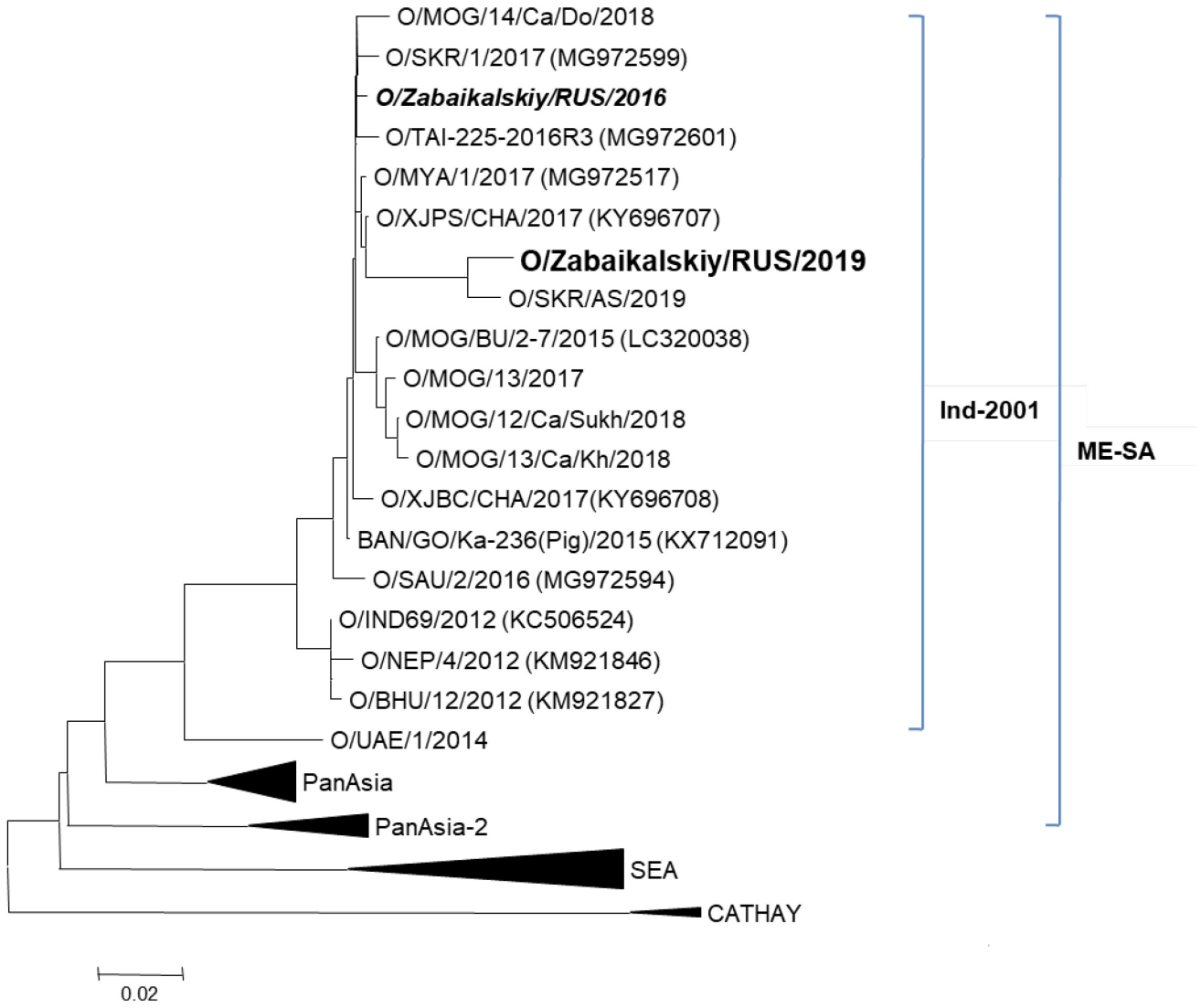


Figure A4.6: O/ME-SA/Ind-2001 in Pakistan

Figure A4.7: New serotype SAT 2 in Egypt

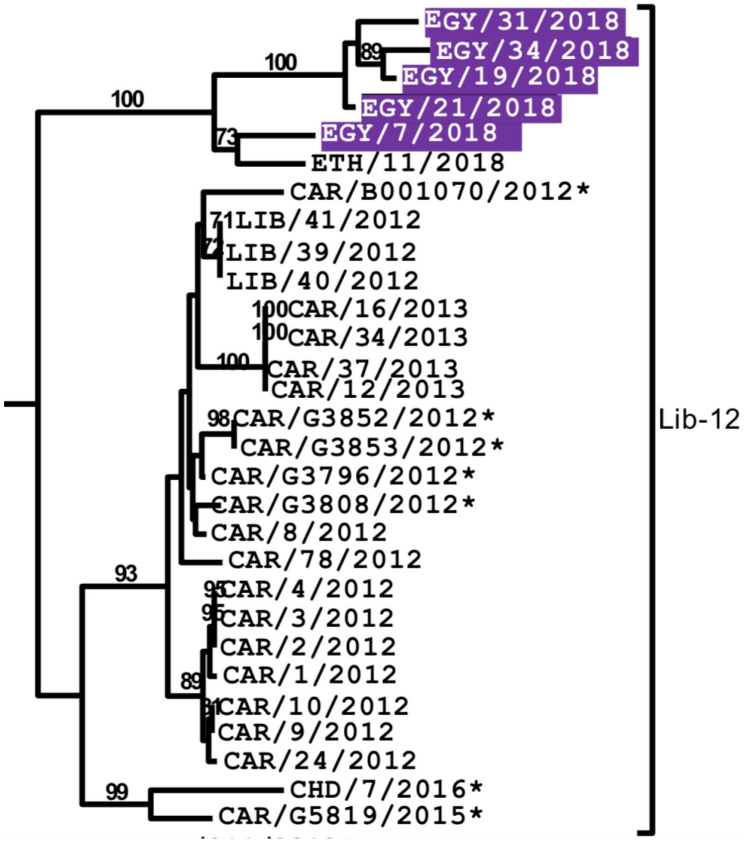


Figure A4.8: O/EA-2 (Zambia and Comoros)

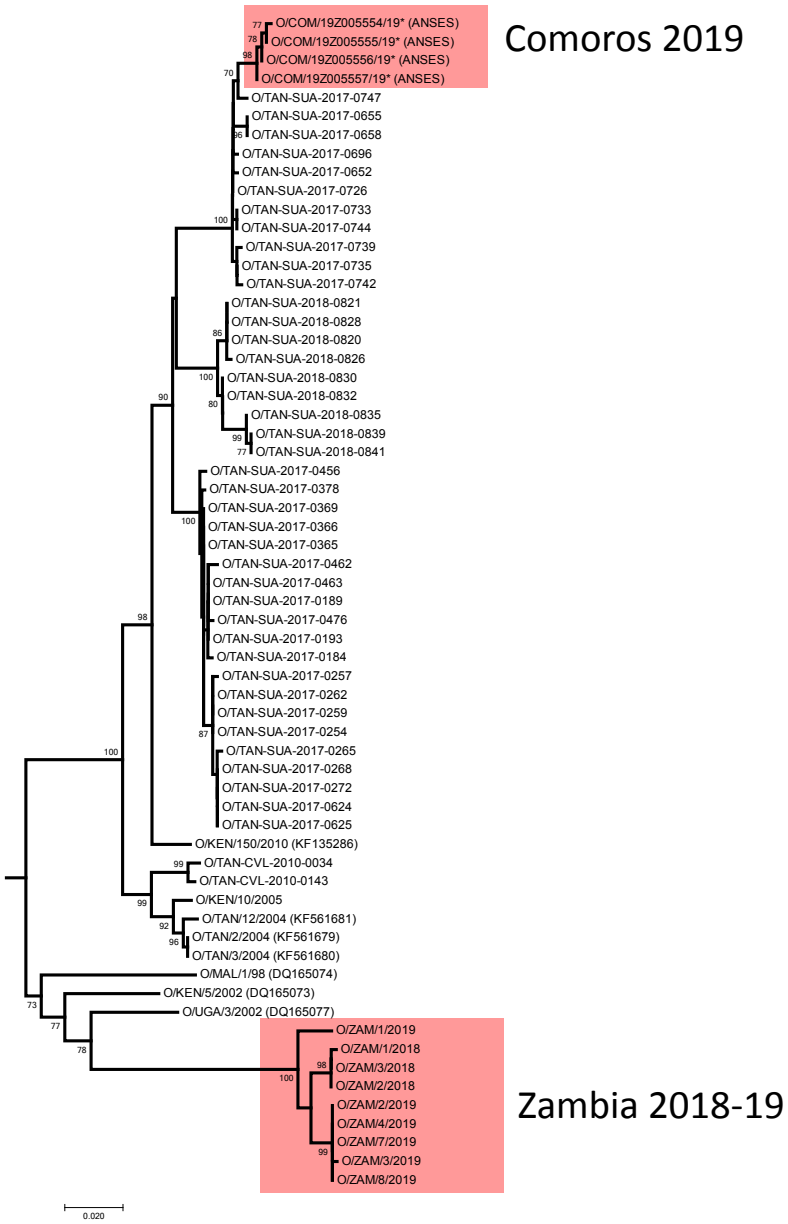


Figure A4.9: SAT 2 in South Africa

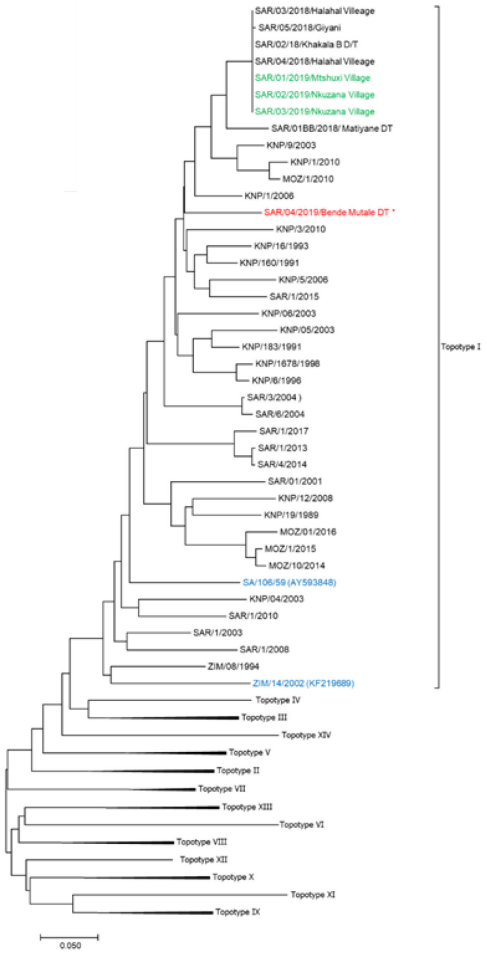
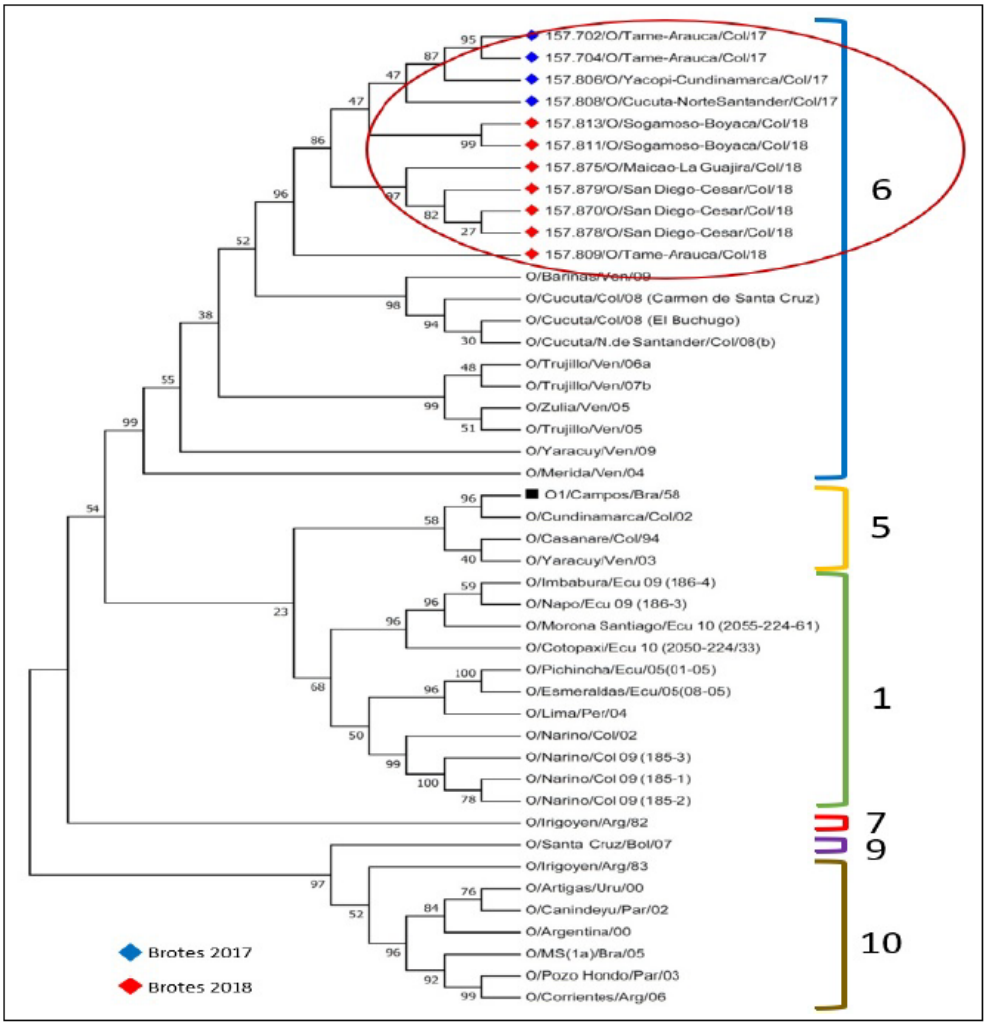


Figure A4.10: Serotype O in Colombia



Appendix 5 - The 14th OIE/FAO FMD Reference Laboratories Network Annual Meeting

3rd – 5th of December 2019

Hosted by Animal and Plant Quarantine Agency (APQA), Republic of Korea

DAY 1

Global Headlines 2019 – WRLFMD

During the first 3 months of 2019, more samples were sent to WRLFMD than are usually received in a year. Key headline events:

- As in past years, serotype O is the predominant serotype followed by serotype A.
- Further expansion of the O/ME-SA/Ind-2001e lineage during 2019 into Pakistan. These new outbreaks raise concern as it is the first time that this lineage has been detected in a West Eurasian country that has the potential for onward spread into countries such as Iran and Turkey.
- Continued outbreaks of O/EA-3 (2018/19) in North Africa (Libya and Morocco) following on from cases due to A/AFRICA/G-IV during 2017. There are now two distinct viral lineages responsible for the cases detected in North West Africa (Maghreb) and North East Africa (Egypt). The shipment of these samples has been difficult and alternative methods have been used to characterise FMD viruses such as lineage specific rRT-PCR, and transfection methods for “live” virus recovery from RNA.
- Retrospective data confirms the presence of the SAT 1 lineage X in Cameroon in 2016.
- There has also been a new incursion of SAT 2/VII lineage into Egypt – most closely related to sequences from Ethiopia.
- New outbreaks of O/EA-2 in central Zambia and Comoros have been caused by two different lineages (15% nt difference). The Comoros lineage is most closely related to

samples collected in Tanzania. The Zambia outbreaks appear to represent a southern movement of the virus.
- An outbreak of SAT 2 in South Africa has resulted in a suspension of FMD-free status

A new document has been prepared to define transboundary connectivity and show how FMD viruses move between pools (see Appendix 1). Please send any feedback or comments on this figure to WRLFMD.

The WRLFMD E-learning course is now available and it is anticipated that this will be run again in 2020 (with EuFMD). A project at WRLFMD is developing a databases for FMD sequences; once this is ready, input will be sought to understand how other Network laboratories will interact with it. Wilna Vosloo highlighted that CSIRO are also working on a system that will have capacity to recognize and interact with different databases - reinforcing the importance of ensuring that these systems are able to communicate with each other.

ACTION O1-19: Other reference laboratories that are not OIE/FAO may also need to sign a type of MoU so that can be shared more easily within the Network, specifically sequencing information. WRLFMD will investigate this further

Pool 1: South East Asia – RRLSEA (Pakchong) Thailand

During 2019, sample submissions (n=118) have been received from Thailand for FMDV detection, using multiplex rRT-PCR and FMDV GD. Serological analyses have detected positive results for serotypes Asia 1, O and A (reflecting annual vaccination with trivalent FMDV vaccines – O. A, Asia 1), while ELISA-typing and sequencing has detected only serotypes A and O with the most common viral lineages being O/ME-SA/PanAsia, O/ME-SA/Ind-2001e and A/ASIA/Sea-97. No serotype Asia 1 has been detected since 1998 in Thailand, although there was an outbreak of Asia 1 in 2017 in Myanmar. The next PTS supplied by RRL-SEA Pakchong will for the first time include an antigen panel for RT-PCR.

Pool 1: East Asia and China (LVRI, China)

Pro-active surveillance using RT-PCR and serological testing is still ongoing in China. During 2019, the serotypes and lineages identified by sequencing (both outbreak and surveillance) were: O/CATHAY, O/ME-SA/Ind-2001e (closely related to viruses in 2018), O/SEA/Mya-98, O/ME-SA/PanAsia (potential re-introduction), and A/ASIA/Sea-97 (possibly due to a new incursion). In 2019 the number of FMD outbreaks has decreased, potentially due to the incursion of ASF which has led to an increase in biosecurity and a decrease in the number of backyard animals.

A PGP study in pigs for both monovalent (serotype O) and bivalent (serotype A and O) vaccines against the O/CATHAY virus O/18074 shows promising results with protection of 100% and 81% respectively. PD_{50} studies have also been carried out using vaccine from nine manufacturers and a strain from the O/ME-SA/Ind-2001 lineage. All vaccines had a PD_{50} above 6. There is currently no international vaccine available in China, only locally produced are available.

Discussion – Surveillance samples (OP fluids) were collected from healthy animals in the field as well as slaughter houses. Questions were raised whether these events should be considered as “outbreaks” according to the OIE Code. The lack of clinical signs could be due to vaccination supressing the clinical presentation of FMD.

Discussion – Vaccines used in China: vaccine does not include O/CATHAY as it is not clear whether this virus is actively circulating in China or whether cases are due to regular virus incursions.

Pool 1: Korea and East Asia (APQA, Republic of Korea)

During January 2019, three FMD cases due to O/ME-SA/Ind-2001e in cattle were reported from the central part of South Korea. These outbreaks led to the culling of 2,272 heads of cattle on 29 farms. This virus is genetically similar to the strains detected in China (99.5%) and Malaysia (98.4 to 98.7%). There have now been twelve outbreaks since 2000 and since 2010 vaccination has been used from international companies for pigs (serotype O) and since 2015 cattle (serotype A and O). Currently, both serotype O and A vaccines are used in cattle and pigs. Plans are in place to carry out a national proficiency test and scientific/technical training courses for the region. Diagnostic kits are being supplied to Myanmar.

Discussion – The use of South America vaccine viruses has been robustly verified in both *in-vitro* and *in-vivo* tests.

Discussion – After an outbreak, if NSP positive animals are found, these animals are re-bled at 3 to 4 weeks later and NSP levels are monitored monthly. Probang testing is not carried out as environmental testing and re-testing of the animals takes place.

Pools 1 and 3 (FGBI-ARRIAH Russia)

Outbreaks due to serotype O have been reported in the regions of Primorsky, Khabarovsk, and Zabaikalsky Krais. VP1 sequencing of 41 samples has identified serotype O/SEA/Mya-98 in Primorsky and Zabaikalsky and O/ME-SA/Ind-2001e in Zabaikalsky. For confirmation of freedom over 20,000 samples were tested by LPBE and it is thought that the positive results are connected to residual antibodies after vaccination in these regions. Samples have also been collected from wild animals to prove freedom of disease; these were all negative. Each year there is movement of Saiga antelope from Mongolia to Russia; in 2018 the laboratory was able to sample these. Although no virus was detected the serum samples were positive for serotype O and NSP.

Vaccines suitable for the buffer zones include those from international vaccine companies; however, regional and state veterinarians and experts tailor which vaccines to use within the buffer zone. No proficiency testing scheme was carried out this year, but training programmes have been undertaken.

Pool 2: India (ICAR-DFMD, India)

No presentation was received.

Pool 3: Turkey (SAP Institute, Turkey)

This year there has been a reduction in the number of samples received. There has also been a decrease in the number of serological positive samples. For 2019, all isolates were from the sublineage O/ME-SA/PanAsia-2^{QOM-15}. Twenty samples were received from Iran (O, A and Asia 1). Vaccine matching indicates that the current circulating strains are covered by the local vaccine which is the only vaccine used in Turkey. No local proficiency testing scheme was undertaken, and no reagents were distributed this year; however, training has occurred. A collaboration with the US to improve biorisk management has also been undertaken.

Pool 4: Kenya-East Africa (Embakasi, Kenya)

Antigen ELISA testing from Kenyan samples has shown serotype O, A, SAT1 and SAT 2 with the most predominant serotype being SAT 1. Twenty samples will be submitted to the WRLFMD shortly. Recent serological testing has provided evidence of high rates of seropostivity within the country (741/1140 sera positive by NSP ELISA). Vaccine matching is

ongoing with SAT 1 being prioritised, results should be available for the final report. Locally produced vaccines are currently being used.

A collaboration project with ARS, Univ. of Minnesota and Kenya wildlife service is studying the transmission dynamics between cattle and buffalo.

Discussion – It is thought that the high number of NSP positive samples is most likely due to the animals previously being infected and not vaccination.

Pool 4: Ethiopia and East Africa (NAHDIC, Ethiopia)

Seventy-six samples from 20 outbreaks were received and typed as serotypes O, A and SAT 2. A subset of viruses were sequenced as serotype O and A. Compared to last year there appears to be a decrease in the proportion of outbreaks caused by SAT 2. SAT 2 and SAT 1 were only detected in a few outbreak samples that were tested by antigen ELISA. These were not sequenced this year as samples were sent to WRLFMD. SAT 1 on antigen ELISA could be due to cross-reactivity as SAT 1 has not been detected for the last 12yrs.

Discussion – A brief update on the East African Network was provided by Abraham Sangula and Daniel Gizaw. There is the potential to organise a skype meeting of the Network through EuFMD support. It is encouraged by the Network that these type of meetings occur as not to lose the momentum within this network.

Pool 5: Nigeria (NVRI, Nigeria)

Serotypes O, A and SAT 2 have been detected but it appears that the IZSLER ELISA could not detect a particular lineage of SAT 1 (as discussed in previous years). Due to limited resources, efforts have been concentrated on outbreak samples, not surveillance. No recent sequencing has been carried out, but the suggestion is that there is continuous circulation of the same lineage in the country. No vaccine matching has been undertaken since 2013. Samples are to be sent to Canada as part of a new collaborative project.

Update from NCFAD Winnipeg, Canada

NCFAD has continued to receive positive samples for Seneca Valley virus (SVV) collected within Canada. As discussed above, NCFAD has new collaborative projects with Nigeria (and Colombia via PANAFTOSA). For the work in Nigeria samples sequenced were serotype O and SAT 2 (2017 and 2018) identifying an equal distribution of serotype O/EA-3 and SAT 2/VII.

Most reagents this year have gone for the supply of commercial kits, including hybridomas and recombinant NSP antigens. Further collaborations include APQA (vaccine studies in cattle), North American FMD Vaccine Bank (use of monoclonal antibodies for vaccine matching and antigenic cartography) and BI (vaccine matching in pigs).

Action – O2-19 – The O/EA-3 sequence data should be shared to study how this lineage is moving across Africa. This could include strains from WRL, ANSES and NCFAD.

Pool 5: West Africa (LNERV, Senegal)

Not able to attend the meeting but they have e-mailed with a short summary. The samples tested this year have all been negative for FMDV.

Pools 4-6: Sub Saharan Africa (BVI, Botswana)

During 2019, samples have been received from Zambia (O/EA-2), Malawi (SAT 2/I) and Namibia (SAT 3/II). There has been a decrease in the number of submission due to financial constraint caused by the drought. For the samples submitted from Botswana no positive cases

have been obtained. Vaccine strains include SAT 2035, SAT 251, SAT 306, SAT 309 and O Manisa; this will be updated next year with new strains received from BI/Merial.

Discussion – Is SAT 3 more widespread? It is difficult to answer this. Perhaps, due to the drought animals are moving to new areas, but many countries do not regularly submit samples.

Pools 4-6: Sub Saharan Africa (OVI, South Africa)

SAT 2 topotype I has been detected by VI and rRT-PCR. The presentation included a SAT 2 phylogenetic tree of the South African strains which appeared to show that there are distinct events taking place in the country. Surveillance activities have been carried out in South Africa, Namibia, Zimbabwe and Uganda. No vaccine matching has been done for these strains. Locally produced vaccines, not yet available on a full scale.

Discussion – The most likely SAT topotype to cause outbreaks outside of Africa is the SAT 2/VII as it is readily transmitted from cattle to cattle (as shown previous in Egypt).

Update from Sciensano – David Lefebvre

Sciensano is now the joint EU-RL with ANSES, France. Sciensano has tested samples from Luxembourg and Ethiopia. The Ethiopian samples were: O/EA-3, O/EA-4 and A/AFRICA/G-IV. Surveillance has also been carried out by serology: NSP ELISA (pigs 2.1%, cattle 24.4%). Sciensano is part of collaborative programs with Nigeria, Burundi and Botswana.

Update from ANSES – Labib Bakkali Kassimi

ANSES is the joint EU-RL with Sciensano, Belgium and more information can be found on the website http://eurl-fmd.anses.fr.

This year, ANSES has received samples from Morocco, Tunisia, Algeria, Mali, Ivory Coast and Comoros. Topotype O/EA-3 was isolated in Morocco, Tunisia, Algeria, Ivory Coast and Mali. For the Comoros topotype O/EA-2 was identified and the isolates appear to be closely related to Tanzania. Comoros represents a new example of the introduction of FMDV into an island that was previously FMDV-free (Mauritius was the previous example).

Thirty-seven countries participated in the Proficiency Testing Scheme in 2019. Reagents have been supplied to regional laboratories.

Discussion – The recent spread of viruses into North Africa could be due to the roads that have recently been built although it is likely that illegal movement of animals still occurs.

Update from IZSLER

IZSLER has received samples from Algeria (ovine and bovine) and carried out tests by ELISA, rRT-PCR, virus isolation and sequencing. Algerian viruses belong to O/EA-3 and these are closely related to those from Libya. Sixteen FTA cards smeared with epithelium tissue, swab or blood from cattle and sheep have also been submitted to IZSLER from Libya. From the FTA cards containing epithelium tissue, rRT-PCR was carried out and the topotype O/EA-3 was identified.

IZSLER has also been involved in a small field vaccine trials which included the Maghreb countries as well as Transcaucasus (Armenia, Azerbaijan and Georgia). Samples were tested by NSP, SP-ELISA and VNT. The conclusions include (1) booster vaccination is necessary and (2) SP-ELISA provides results consistent with VNT for the booster vaccination. Training has been provided as well as a tailored proficiency testing scheme (PTS) for Cyprus and

Turkey. A regional PTS was also carried out. A total of 2,106 kits have been supplied to 54 countries, mostly for SP serotype O. Collaborations continue with University of Glasgow and Tanzania, this is a longitudinal study from 2012 to 2018 and includes both clinical samples as well as sera.

Discussion –. Currently IZSLER is developing a multiplex LFD using later flow with four lines (O, A, Asia 1 and PanFMD). This will use the same monoclonals as are currently in the antigen ELISA kit. S. Korean lateral flow multiplex to look at the different serotype is being used in North Africa. For subsequent molecular testing, it is not clear how long LFDs and FTA cards can be stored for before being processed. However, it is recommended that an original sample is kept alongside the LFDs and FTA cards.

Pool 7: South America (PANAFTOSA, Brazil)

Except for Venezuela where the FMD status is unknown, there have been no suspected cases of FMD in South America in 2019. A retrospective genetic study looking at the FMDV isolates from Colombia (Serotype O/Euro-SA lineage 6) highlights a relationship between the viruses of the Andean region (90% similarity). Venezuela does not have OIE-recognized FMDV status and there is concern that the vaccination coverage is dropping. There is also concern of illegal trade because of the increase in meat prices elsewhere.

Brazil will suspend vaccination in 2023. It is expected that vaccination will cease in some regions in 2020 and that surveillance for FMDV will increase. PANAFTOSA has carried out vaccine matching and EPP for the Colombian outbreak strains; the O1 Campos strain has good vaccine matching and EPP results against O/Colombia 2018 both after single and booster vaccination. The recommendation to Colombia is to strengthen vaccination strategy to avoid immunity deficiencies (recommended vaccine coverage >80%).

Argentina is the only country in South America to use tetravalent vaccine that contains A/Arg/2001 as well as C3 Indaial; all others use O1 Campos and A24 Cruzeiro.

A proficiency test has been organised for 12 countries in the region and a training course has been delivered, along with a simulation exercise. Reagents have also been supplied to the region.

Discussion – Vaccine matching is carried out on trivalent vaccines using both single and booster BVS.

Update from CSIRO/AAHL, Australia

Recent work has shown that inactivation of epithelial samples works with RNAShield but takes 24hrs, which is too long and additional work is being carried out to facilitate faster inactivation. An additional study has shown that a more cost-effective protocol for rRT-PCR can be established by decreasing the volumes and amount of master mix used in the test – without negatively influencing assay performance.

A new model for producer-led surveillance which improves partnership among stakeholders has been developed, and the strengthening of the model to study the potential spread and control of outbreaks, including the cost benefit of vaccination, is in place. In some situations, vaccination decreases the cost (for small outbreaks) but in others (larger outbreaks of longer duration) it didn't make a difference.

Recent collaborative studies have shown that the A/GVII (from BI) vaccine does not protect against A/ASIA/IRN-05 field isolates (approx. 2 PD_{50}).

Discussion – Is FMDV RNA is infectious? The network felt that there was a low risk of this and that there needs to be a statement that from a biosafety point of view, RNA is not infectious.

Update from FADLL USA – presented by Don King

NBAF is to replace ARS and APHIS and Dr. Alfonso Clavijo will join NBAF as director. In order to prepare for the move viruses have been sequenced from the repository. There will now be a separate US vaccine bank; however, the US will still be part of the North American vaccine bank. A local PTS as well as training has been carried out.

ACTION O8-19: The annual report will be started in the New Year. Please reply to Mark Henstock e-mail regarding laboratory reports for 2019 activities

Environmental sampling: a new approach to enhance FMD surveillance? A short presentation was provided to review the benefits of environmental sampling where swab/cloth samples can be collected in areas where animals are present (such as farms truck, markets etc..). This sampling approach can be carried out using dust cloths and results have shown that viral RNA can be collected 60 days after the last clinical cases. **Introduction/request for collaboration:** Claire Colenutt and Simon Gubbins from The Pirbright Institute are looking for partners to validate environmental sampling for FMD. Please contact simon.gubbings@pirbright.ac.uk for further details.

DAY 2

Global FMD strategy with emphasis on vaccines -Samia Metwally

West and Central Africa is where many countries are still in PCP stage 0. The total investment has been $56M and gaps including vaccine and vaccination have been identified. These include low vaccine coverage, unaffordable vaccine and the ineffectiveness of the vaccination program. Actions are to be taken by international organisation and partners (GF-TADs FMD WG) to establish a prequalification system (including OIE, FAO and EuFMD). In addition, this will include designated vaccine quality control reference centres in Africa, Asia and Middle East. Training of PVM will include serological tests for PVM supported by vaccine producers, GFRA and reference centres. A list of regional lab network objectives has been defined and support from the Network for training will be requested.

Discussion - Regional Expert Group in South East Asia met twice this year to write guidance documents for testing algorithms for serology and molecular techniques. These documents have gone out for consultation.

Challenges of establishing a QA/QC pipeline for FMDV vaccines – the importance of heterologous response – Don King

This presentation introduced a new OIE Twinning Project between AU-PANVAC and WRLFMD which has the goal to establish a pipeline for vaccine QA/QC for endemic countries in Africa. It is anticipated that this project will connect with OIE/FAO Network and Dr Nick Nwankpa has been invited to the meeting this year to build this connection. The project will focus on heterologous testing of the final formulated product supplied to the customer and adopting standardised protocols for post-vaccination sampling using the PVM guidelines. A gap still exists to define the “correlates of protection” using the available serological tests.

This presentation also introduced the AgResults FMD vaccine challenge project which will launch in January 2020, managed by GalvMed. This project will supplement the cost of the

vaccine; the country gains because a high quality vaccine will be delivered at a lower cost. This project is a long-term investment over at least seven years.

Establishment of an independent FMD Vaccine quality control system at AU-PANVAC: An Introduction – Nick Nwankpa

AU-PANVAC international is concerned with independent quality control of all veterinary vaccines produced or imported into Africa. AU-PANVAC falls under the African Union Technical Centre and was originally established for Rinderpest. AU-PANVAC is an OIE collaborating centre, FAO reference centre, FAO/OIE Rinderpest holding facility, ISO 9001-2015 certified and ISO 17025 accredited. PANVAC carries out five different test: identities, sterility (free of extraneous agents), innocuity, efficacy and stability. There are a total of 12 tests for each batch of vaccine. Currently, AU-PANVAC does not have capacity for QC for FMD vaccines. Currently a MoU is in place with BVI for the control of foot-and-mouth disease and funding from US-DTRA and SANDIA lab is investing in a new laboratory.

Harmonisation of serological approaches and selection of FMDV reference antigens and sera for endemic settings in (East) Africa – Anna Ludi

A technical presentation was provided on the AU-PANVAC twinning project (and links to the AgResults initiative). This led to active discussion between delegates to consider the approaches that should be used for vaccine QA-QC as well as what the criteria for acceptance should be. The heterologous testing approach proposed by WRLFMD/AU-PANVAC was broadly endorsed and the Network agreed to contribute to work to select FMD viruses for a common Reference Panel (initially covering virus lineages in East Africa). There was agreement on the following points:

1. The method to select the Reference virus panel will initially be based on phylogenetic analysis. The viruses selected will then be tested against a panel of serum before the final panel will be selected. The Reference virus panel will be kept as small as possible due to the possibility of developing diagnostic reagents with these strains, but aim include representatives of each currently circulating clade. NB: It is not essential that all sequenced viruses are included since some viral clades may be extinct
2. Testing should encompass the final formulated vaccine
3. The panel will need to be reviewed (annually – at this meeting) to insure it stays up to date

The criteria of acceptance of a vaccine needs to be clearly defined. Current feedback from Ag-Results indicates that a 70% pass rate (at serotype level) will be defined for the initiative that will be launched in January 2020. The following concerns were raised:

- There was concern that these criteria (i.e, 70% - where only 3 out of 4 viruses in each serotype need to pass) might lead to a gap in vaccine coverage
- The criteria should evaluate a vaccine using sera collected from multiple animals (to accommodate animal-to-animal variability in responses)
- The serological criteria used to define a “pass” needs clarification. One possibility is to use the values described in the Barnett paper, or perhaps a more pragmatic a 1/100 (ELISA) or 1/45 (VNT) could be adopted. Validation of these values (espec. before Jan 2020) will not be possible since there is not enough data for heterologous protection for African viruses (similar to the EPP table used in S. America).

Nagoya Protocol – Pascal Hudelet

The Nagoya Protocol states that countries have sovereign rights over their natural genetic resources (genetic material with actual or potential value for future generations of humanity). To use genetic material, you must obtain formal approval from the country of origin and negotiate or obtain evidence of mutually agreed terms with the provided country. This presentation highlighted the impacts of the Nagoya Protocol on the generation of new FMD vaccine seed strains where countries have (i) not responded to requests from vaccine producers, (ii) asked for an unrealistic proportion of vaccine profits, or (iii) refused to transfer rights without local investment into vaccine capacity and research. This is causing long delays for the development of new FMDV master seed strains and these issues may also impact upon the development of diagnostic kits.

ACTION O5-19: There is a tri group reviewing Nagoya (representing OIE/FAO/WHO). Samia Metwally will get the most updated information from this committee.

Appendix 5-1: Transboundary connectivity of FMD (draft)