

Reference Laboratory Contract Report¹
October-December 2008

Foot-and-Mouth Disease

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Summary

There were no outbreaks officially reported in FMD-free countries that did not practice vaccination between October and December 2008.

ASIA

China: An outbreak of FMD was detected on 06/11/2008 in Qiangganyu, Gangu, Tianshui, Gansu Province. Typing at the National FMD Reference Lab indicted the type to be **type Asia 1**.

Laos: An outbreak of FMD was detected at Boten cao, Namtha, Luangnamtha Province on 07/10/2008. Typing at the National Animal Health Center Laboratory showed the causative virus to be **type O**.

AFRICA

Botswana: On 20/10/2008 an outbreak of FMD was detected on Newlook Farm, Kuke, Ghanzi, Ghanzi Province. Samples submitted to the Botswana Vaccine Institute were reported as **type SAT 2**. The farm was depopulated and the incident resolved by 03/12/2008.

Malawi: In September 2008, a suspected outbreak of FMD was reported on Kaombe Ranch, Nsanje, southern Malawi (the first since 2003). Tracing the origin of the infected animals indicated that some of the animals were brought in from an area close to Lengwe National Park which contains African buffalo. These were probably the source of the 2003 outbreak. Further outbreaks were reported at Thobwa, Ngabu, Chikwawa, Southern Province (05/09/2008), Mnthumba Crush, Chikwawa, Southern Province (25/10/2008) and Mnthumba village (11/11/2008). Samples submitted to the Onderstepoort Veterinary Institute were identified as **type SAT 2**. A total of 79,186 cattle were vaccinated in the two affected districts of Chikwawa and Nsanje. The disease morbidity was very low. No further outbreaks have occurred and the epidemic was resolved by 03/12/2008.

South Africa: FMD virus was detected in African buffalo at Happy Lands, Maruleng, Phalaborwa, Limpopo Province on 05/12/2008, although no disease was observed. FMDV **type SAT 2** was isolated at the Onderstepoort Veterinary Institute. All buffalo on the farm were immediately moved back into the Infected Zone. No cattle were kept on the affected farm or adjacent farms. The FMD free status of South Africa was not affected as the outbreak occurred in the FMD Buffer Zone. The incident was resolved by 12/12/2008.

WRL vaccine recommendations remain unchanged from the previous report (Annexe 4). However, the continued dominance of the FMDV serotype A Iran 05 strain and the poor antigenic match to A22 Iraq vaccine demonstrated against recent Turkish isolates of the A Iran 05 strain (named A-Iran-05^{ARD-07}) necessitate further investigation of alternative vaccine strains.

Results from samples received at WRL (status of samples being tested) are shown in Table 1 and a complete list of clinical sample diagnostics made by the WRL between October and December 2008 is shown in annexe 1 Table A. A record of all samples received to IAH-Pirbright (October-December 2008) and their geographical locations are shown in annexe 1 Table B and Figure 1.

An up-to-date list and reports of FMD viruses characterised by sequencing can be found at the following website: http://www.wrlfmd.org/fmd_genotyping/2008.htm

Table 1: Status of sequencing of samples received recently to WRLFMD

Batch	Country	Serotype	No. of isolates	Status
WRLFMD-2008-00028	Bhutan	O	2	Completed
WRLFMD-2008-00029	Botswana	SAT 2	2	Completed
WRLFMD-2008-00031	Ethiopia	A	3	Completed
WRLFMD-2008-00031	Ethiopia	O	8	Completed
WRLFMD-2008-00033	Bahrain	A	2	Completed
Total			17	

Detailed genotyping results from the WRLFMD

ASIA

Bahrain (type A)

Two FMD type A viruses were isolated from samples received in November. The last known occurrence of type A in Bahrain was in 1965. Both virus isolates belonged to the A-Iran-05 lineage (ASIA toptotype) (Annex 2, Figure 1).

Bhutan (type O)

Two type O viruses were examined and found to belong to the PanAsia-2 lineage of the ME-SA toptotype, a strain currently present throughout the Middle East (Annex 2, Figure 2). They were also related to isolates found in Bhutan in 2007.

AFRICA

Botswana (type SAT 2)

Two viruses isolated from the outbreak in Ghanzi Province were examined. They were closely related to earlier virus isolates from the Maun Veterinary area to the north (Annex 2, Figure 3).

Ethiopia (types O and A)

Eight FMD type O viruses were sequenced and compared to previously isolated viruses. They were all closely related to each other and to some from Ethiopia in 2007 (Annex 2, Figure 4). Three type A viruses were related to an Ethiopian isolate from 2007 and to viruses from Kenya (2005) and Egypt (2006) (Annex 2, Figure 5).

Vaccine matching

Two FMDV type O isolates (O Bhu 2/2008 and O Bhu 3/2008) from Bhutan collected in 2008 and one FMDV type SAT1 isolate (SAT1 BOT 22/2006) from Botswana collected in 2006 were further characterised by two dimensional virus neutralisation test and/or liquid phase blocking ELISA (see Annex 1; TABLE C). The results showed that both isolates from Bhutan were antigenically close to all of O BFS 1860, O Ind R2/75 and O Kaufbeuren vaccine strains and were also matched with O1 Manisa. SAT1 BOT 22/2006 was antigenically matched with both SAT1 RHO 12/78 and SAT1 BOT 1/68.

Annex 1.

Table A: Summary of clinical sample diagnostics made by the WRL between October and December 2008

Country	WRL for FMD Sample Identification	Animal	Date of Collection	Results		
				VI/ELISA	RT-PCR	Final report
BAHRAIN	BAR 4/2008	Cattle	17.11.08	NVD	Negative	NVD
	BAR 5/2008	Cattle	17.11.08	NVD	Positive	FMDV GD
	BAR 6/2008	Cattle	24.11.08	A	Positive	A
	BAR 7/2008	Cattle	24.11.08	A	Positive	A
BOTSWANA	BOT 16/2008	Cattle	04.10.08	SAT 2	Positive	SAT 2
	BOT 17/2008	Cattle	04.10.08	NVD	Positive	FMDV GD
	BOT 18/2008	Cattle	04.10.08	SAT 2	Positive	SAT 2
BHUTAN	BHU 1/2008	Cattle	12.09.08	NVD	Positive	FMDV GD
	BHU 2/2008	Cattle	12.09.08	O	Positive	O
	BHU 3/2008	Cattle	12.09.08	O	Positive	O
ETHIOPIA	ETH 7/2008	Cattle	08.01.08	A	Positive	A
	ETH 8/2008	Cattle	08.01.08	A	Positive	A
	ETH 9/2008	Cattle	01.08.08	A	Positive	A
	ETH 10/2008	Cattle	26.08.08	NVD	Positive	FMDV GD
	ETH 11/2008	Cattle	26.08.08	NVD	Positive	FMDV GD
	ETH 12/2008	Cattle	26.08.08	NVD	Positive	FMDV GD
	ETH 13/2008	Cattle	19.10.08	O	Positive	O
	ETH 14/2008	Cattle	19.10.08	NVD	Negative	NVD
	ETH 15/2008	Cattle	19.10.08	O	Positive	O
	ETH 16/2008	Cattle	19.10.08	NVD	Negative	NVD
	ETH 17/2008	Cattle	19.10.08	NVD	Negative	NVD
	ETH 18/2008	Cattle	19.10.08	NVD	Negative	NVD
	ETH 19/2008	Cattle	19.10.08	O	Positive	O
	ETH 20/2008	Cattle	19.10.08	O	Positive	O
	ETH 21/2008	Cattle	19.10.08	O	Positive	O
	ETH 22/2008	Cattle	19.10.08	NVD	Positive	FMDV GD
	ETH 23/2008	Cattle	21.10.08	O	Positive	O
	ETH 24/2008	Cattle	21.10.08	O	Positive	O
	ETH 25/2008	Cattle	21.10.08	O	Positive	O
	ETH 26/2008	Cattle	01.11.08	NVD	Negative	NVD
MALAYSIA	MAY 1/2008	Cattle	26.03.08	NVD	Positive	FMDV GD
	MAY 2/2008	Cattle	29.05.08	NVD	Positive	FMDV GD
	MAY 3/2008	Cattle	18.06.08	NVD	Positive	FMDV GD

TOTAL : 33

FMD(V) foot-and-mouth disease (virus)
 GD genome detected
 VI/ELISA FMDV serotype identified following virus isolation in cell culture and antigen ELISA
 RT-PCR reverse transcription polymerase chain reaction on epithelial suspension for FMD viral genome
 NVD no foot-and-mouth disease, swine vesicular disease or vesicular stomatitis virus detected

TABLE B: Summary of samples collected and received to IAH-Pirbright (October-December 2008)

Country	No. of samples	Virus isolation in cell culture/ELISA								RT-PCR for FMD (or SVD) virus (where appropriate)		
		FMD virus serotypes			SVD virus	NVD	Positive		Negative			
		O	A	C			SAT 1	SAT 2		SAT 3	Asia	
BAHRAIN	4	-	2	-	-	-	-	-	-	2	3	1
BHUTAN	3	2	-	-	-	-	-	-	-	1	3	-
BOTSWANA	3	-	-	-	-	2	-	-	-	1	3	-
ETHIOPIA	20	8	3	-	-	-	-	-	-	9	15	5
MALAYSIA	3	-	-	-	-	-	-	-	-	3	3	-
TOTAL	33	10	5	-	-	2	-	-	-	16	27	6

VI/ELISA FMD (or SVD) virus serotype identified following virus isolation in cell culture and antigen detection ELISA
 FMD foot-and-mouth disease
 SVD swine vesicular disease
 NVD no FMD, SVD or vesicular stomatitis virus detected
 RT-PCR reverse transcription polymerase chain reaction for FMD (or SVD) viral genome

Figure 1. Geographical locations of clinical sample diagnostics made by the WRL between October and December 2008

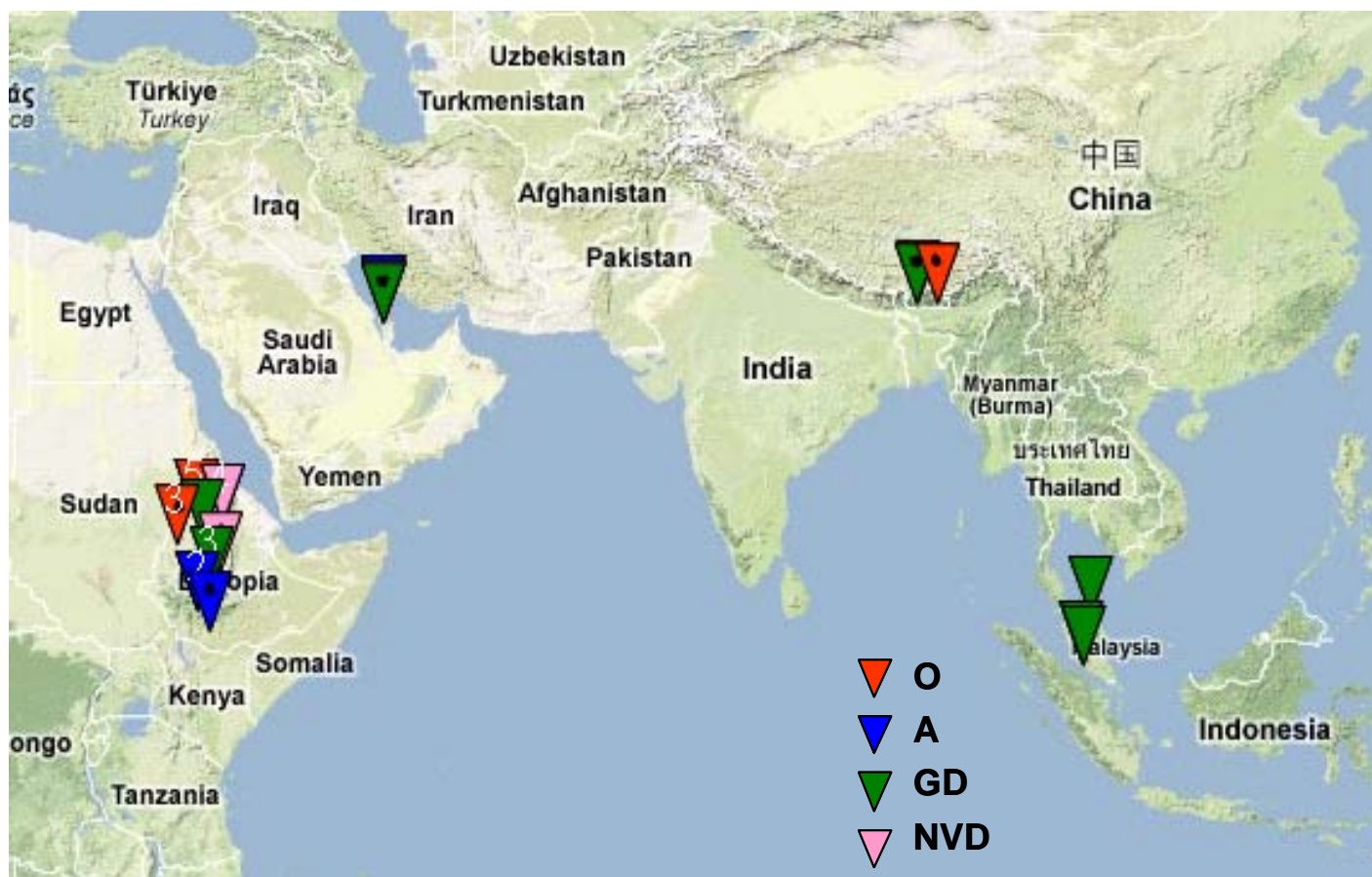


TABLE C: Antigenic characterisation of FMD field isolates by matching with vaccine strains by VNT and/or LPBE – r₁ value data from 1st October to 31st December 2008

r₁ Values by neutralisation test or LPBE against vaccine strains below					
Field Isolate:	BFS 1860	O Ind R2/75	O Kaufbeuren	O Manisa	
	VNT	VNT	VNT	VNT	LPBE
O Bhu 2/2008	0.75	1.0	1.0	0.38	0.86
O Bhu 3/2008	0.84	1.0	0.81	0.39	0.22

Field Isolate	r₁ Values by LPBE	
	SAT1 Bot 1/68	SAT1 Rho 12/78
SAT1 Bot 22/2006	0.75	0.25

Interpretation of r₁ values

In the case of VNT:

r₁ = ≥ 0.3. Suggests that there is a close relationship between field isolate and vaccine strain. A potent vaccine containing the vaccine strain is likely to confer protection.

r₁ = < 0.3. Suggests that the field isolate is so different from the vaccine strain that the vaccine is unlikely to protect

In the case of ELISA:

r₁ = 0.4-1.0. Suggests that there is a close relationship between field isolate and vaccine strain. A potent vaccine containing the vaccine strain is likely to confer protection.

r₁ = 0.2-0.39, Suggests that the field isolate is antigenically related to the vaccine strain. The vaccine strain might be suitable for use if no closer match can be found provided that a potent vaccine is used and animals are preferably immunised more than once.

r₁ = <0.2. Suggests that the field isolate is so different from the vaccine strain that the vaccine is unlikely to protect

Annex 2: Phylogenetic analysis of characterised FMDV isolates

Report on FMDV A from Bahrain in 2008
 Batch: WRLFMD/2008/00033

Software: MEGA 4.0
 No. of Taxa : 174
 Data File : n:\evd\meg\db\fmvd\la\BAR2008a.meg
 Data Title : Bahrain 2008
 Data Type : Nucleotide (Coding)
 Analysis : Phylogeny reconstruction
 Tree Inference : =====
 ->Method : Neighbor-Joining
 ->Phylogeny Test and options : Bootstrap (1000 replicates; seed=31332)
 Include Sites : =====
 ->Gaps/Missing Data : Pairwise Deletion
 ->Codon Positions : 1st+2nd+3rd+Noncoding
 Substitution Model : =====
 ->Model : Nucleotide: Kimura 2-parameter
 ->Substitutions to Include : d: Transitions + Transversions
 ->Pattern among Lineages : Same (Homogeneous)
 ->Rates among sites : Uniform rates
 No. of Sites : 645
 No Of Bootstrap Reps = 1000
 Only bootstrap values of 70% and above are shown

* , not a WRLFMD Ref. No.

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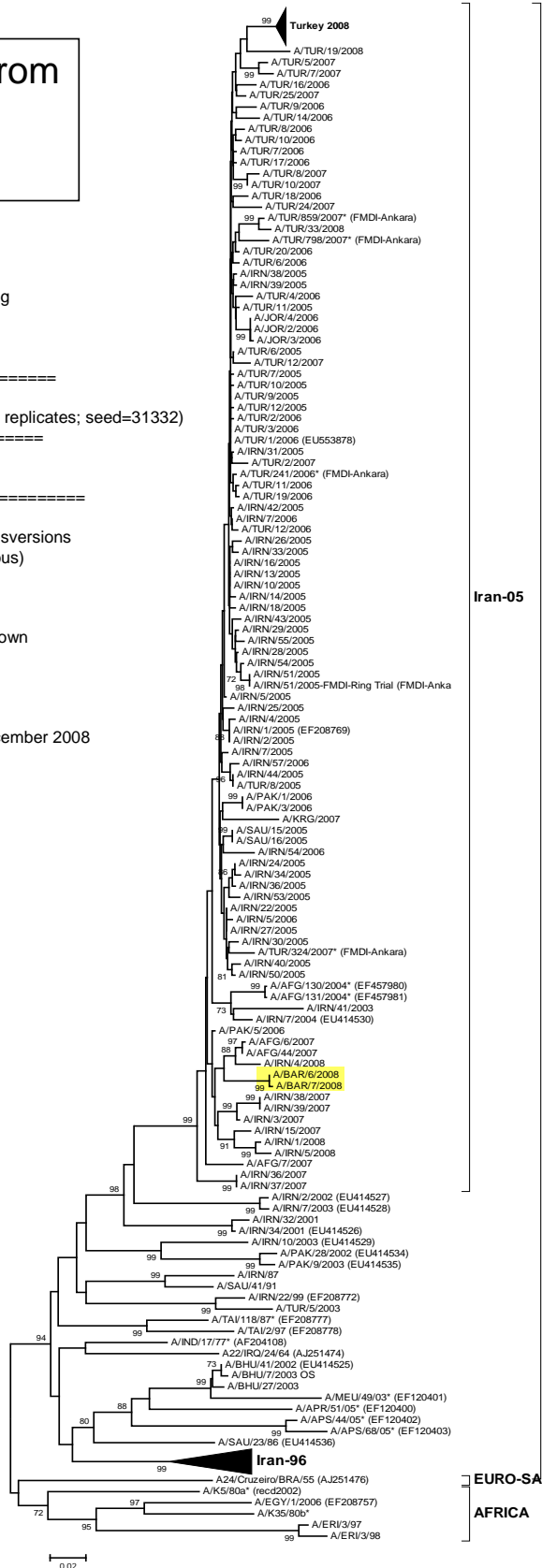


Figure 1. FMDV type A in Bahrain.

Report on FMDV O from Bhutan in 2008

Software: MEGA 4.0
 No. of Taxa : 89
 Data File : n:\evd\meg\db\fmdv\o\BHU2008a.meg
 Data Title : Bhutan 2008
 Data Type : Nucleotide (Coding)
 Analysis : Phylogeny reconstruction
 Tree Inference : =====
 ->Method : Neighbor-Joining
 ->Phylogeny Test and options : Bootstrap (1000 replicates; seed=64238)
 Include Sites : =====
 ->Gaps/Missing Data : Pairwise Deletion
 ->Codon Positions : 1st+2nd+3rd+Noncoding
 Substitution Model : =====
 ->Model : Nucleotide: Kimura 2-parameter
 ->Substitutions to Include : d: Transitions + Transversions
 ->Pattern among Lineages : Same (Homogeneous)
 ->Rates among sites : Uniform rates
 No. of Sites : 642 (VP1)
 No Of Bootstrap Reps = 1000
 Only bootstrap values of 70% and above are shown

*, not a WRLFMD Ref. No.

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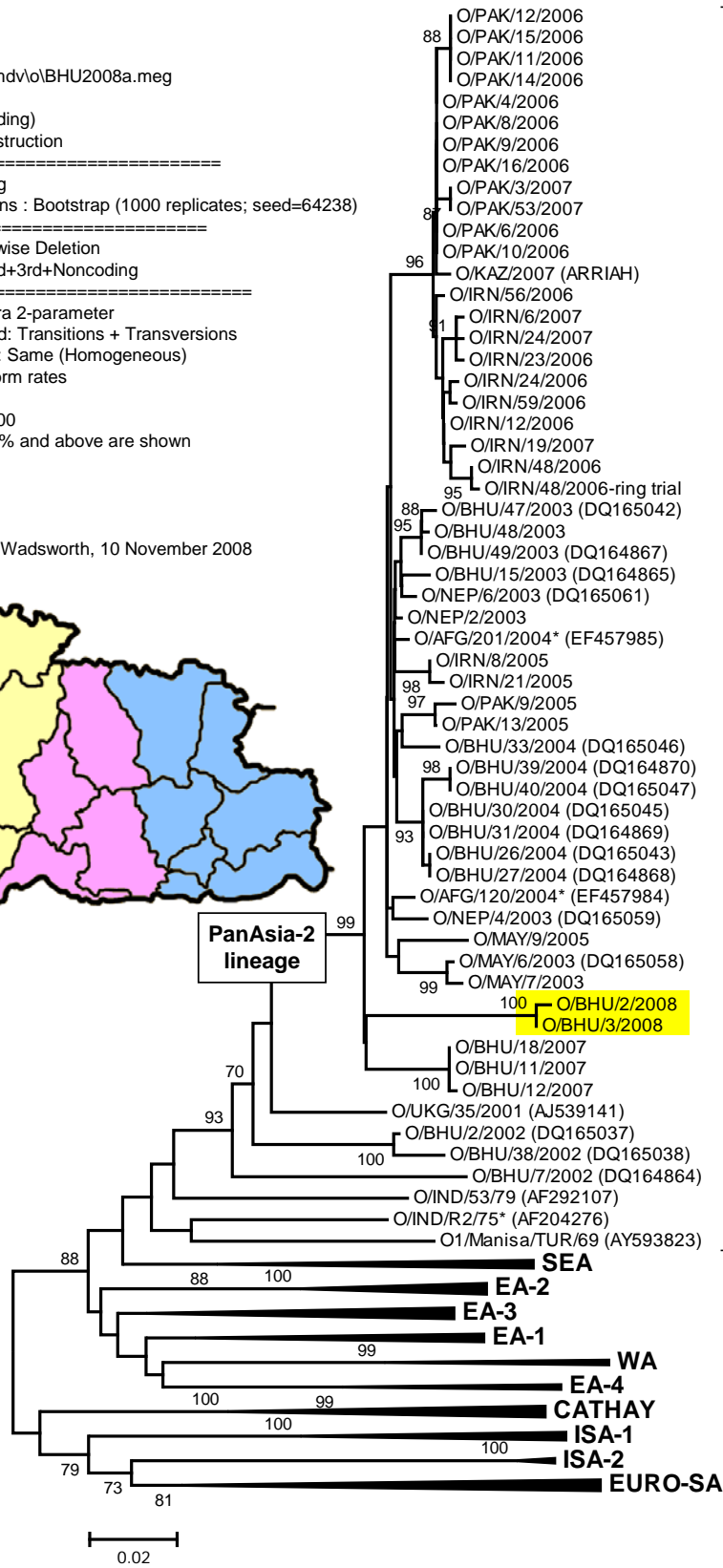
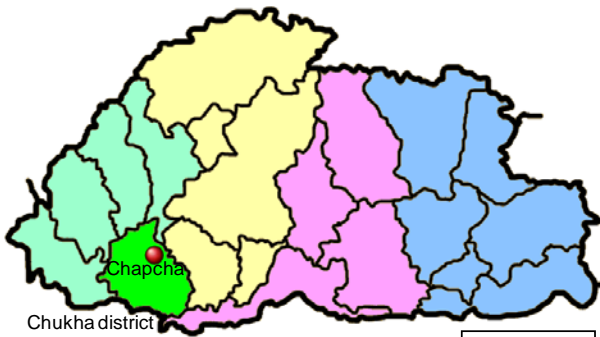
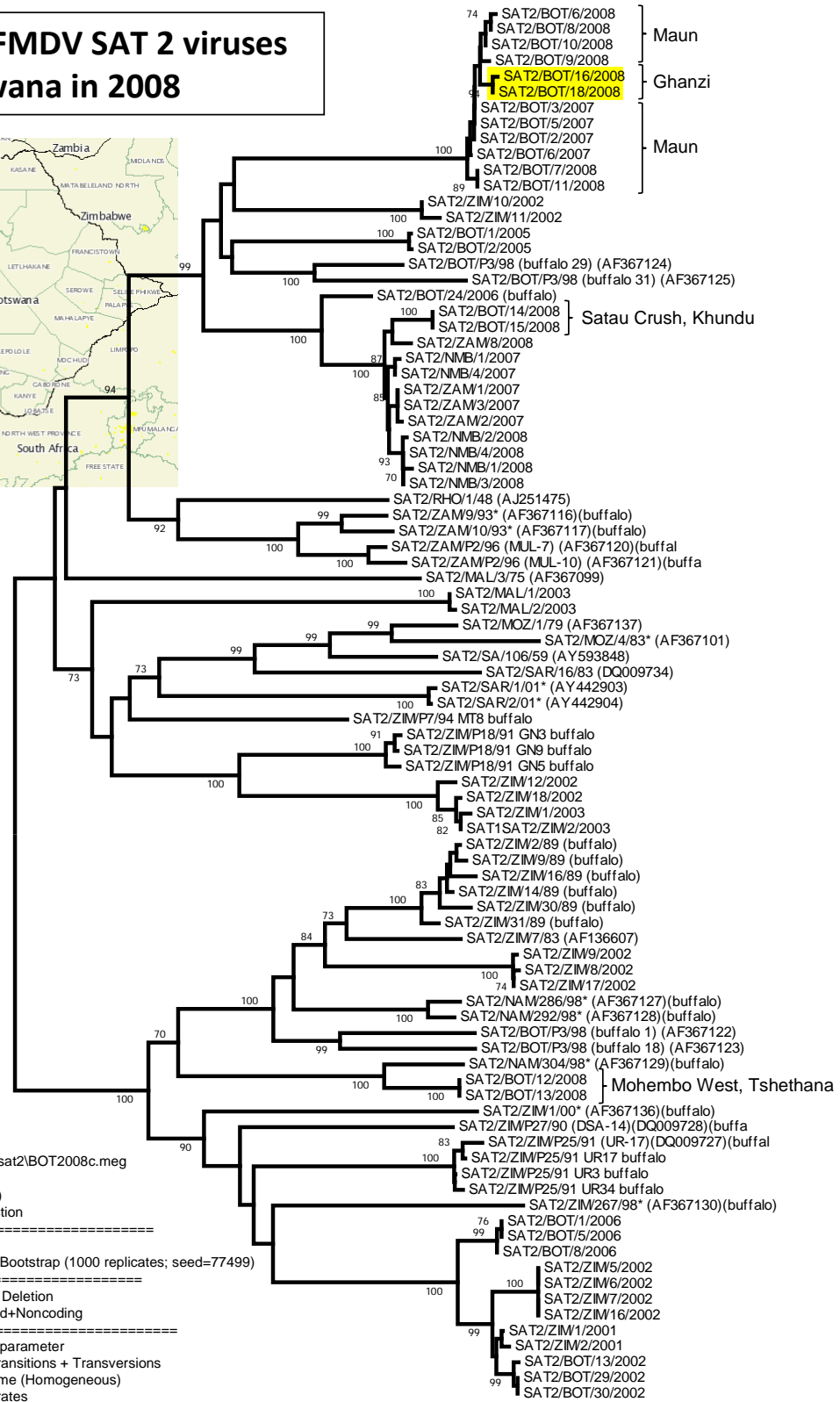
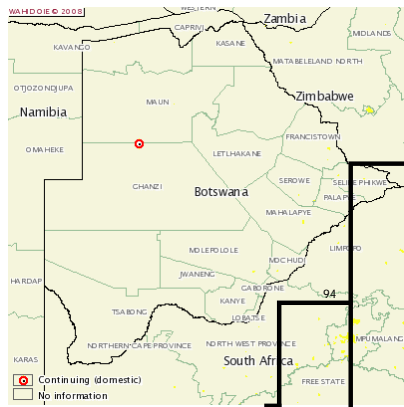


Figure 2. FMDV type O in Bhutan.

Report on FMDV SAT 2 viruses from Botswana in 2008



No. of Taxa : 89
 Data File : n:\evd\meg\db\fmdv\sat2\BOT2008c.meg
 Data Title : Botswana 2008
 Data Type : Nucleotide (Coding)
 Analysis : Phylogeny reconstruction
 Tree Inference : =====
 ->Method : Neighbor-Joining
 ->Phylogeny Test and options : Bootstrap (1000 replicates; seed=77499)
 Include Sites : =====
 ->Gaps/Missing Data : Pairwise Deletion
 ->Codon Positions : 1st+2nd+3rd+Noncoding
 Substitution Model : =====
 ->Model : Nucleotide: Kimura 2-parameter
 ->Substitutions to Include : d: Transitions + Transversions
 ->Pattern among Lineages : Same (Homogeneous)
 ->Rates among sites : Uniform rates
 No. of Sites : 648
 No Of Bootstrap Reps = 1000

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Figure 3. FMDV type SAT 2 in Botswana.

Report on FMDV O from Ethiopia in 2008

Software: MEGA 4.0
 No. of Taxa : 164
 Data File : n:\evd\meg\db\fmv\o\ETH2008a.meg
 Data Title : Ethiopia 2008
 Data Type : Nucleotide (Coding)
 Analysis : Phylogeny reconstruction
 Tree Inference : =====
 ->Method : Neighbor-Joining
 ->Phylogeny Test and options : Bootstrap (1000 replicates;
 seed=64238)
 Include Sites : =====
 ->Gaps/Missing Data : Pairwise Deletion
 ->Codon Positions : 1st+2nd+3rd+Noncoding
 Substitution Model : =====
 ->Model : Nucleotide: Kimura 2-parameter
 ->Substitutions to Include : d: Transitions + Transversions
 ->Pattern among Lineages : Same (Homogeneous)
 ->Rates among sites : Uniform rates
 No. of Sites : 642
 No Of Bootstrap Reps = 1000
 Only bootstrap values of 70% and above are shown

*, not a WRLFMD Ref. No.

N.J. Knowles and J. Wadsworth, 6 January 2009

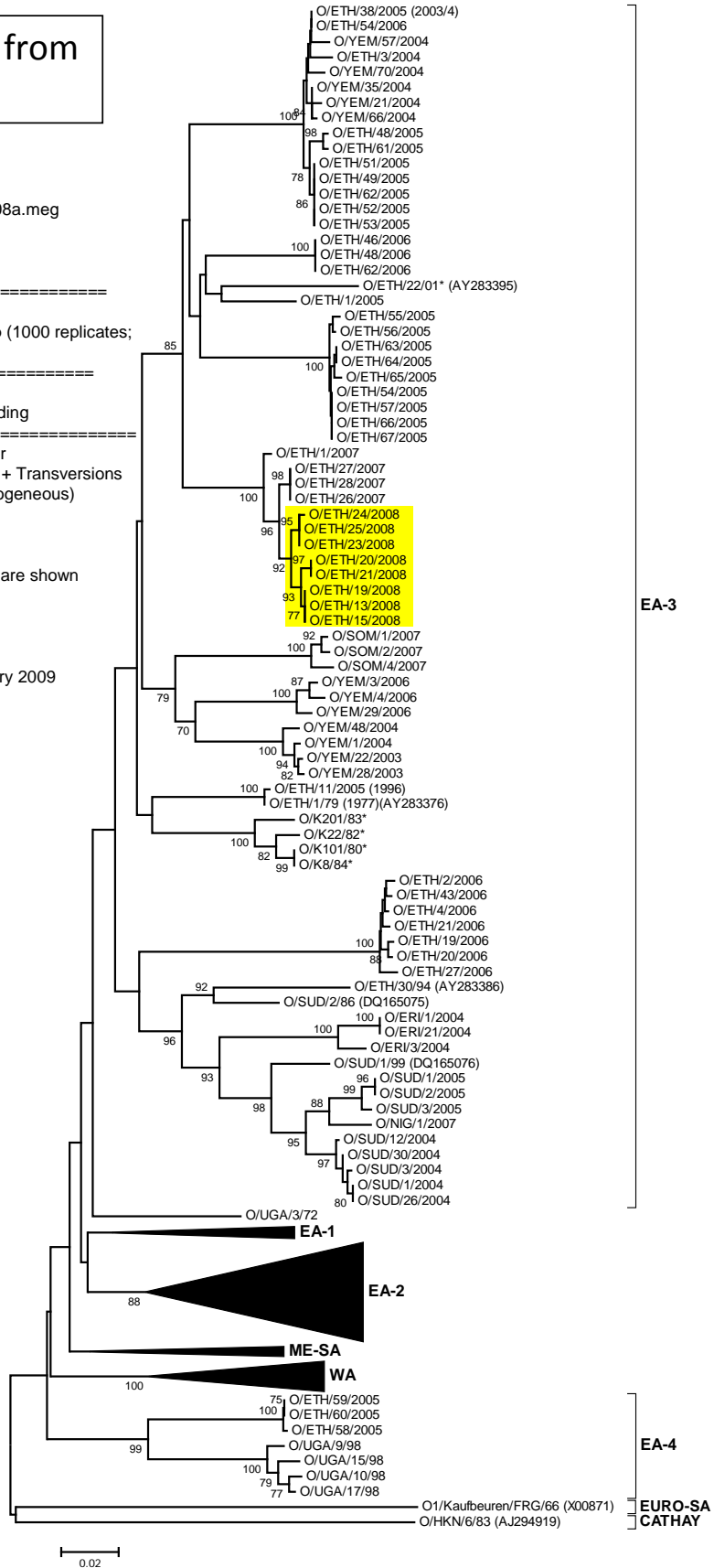


Figure 4. FMDV type O in Ethiopia.

Report on FMD A viruses from Ethiopia in 2008

Software: MEGA 4.0
 No. of Taxa : 122
 Data File : n:\evd\meg\db\fmv\la\ETH2008a.meg
 Data Title : Ethiopia 2008
 Data Type : Nucleotide (Coding)
 Analysis : Phylogeny reconstruction
 Tree Inference : =====
 ->Method : Neighbor-Joining
 ->Phylogeny Test and options : Bootstrap (1000 replicates; seed=85724)
 Include Sites : =====
 ->Gaps/Missing Data : Pairwise Deletion
 ->Codon Positions : 1st+2nd+3rd+Noncoding
 Substitution Model : =====
 ->Model : Nucleotide: Kimura 2-parameter
 ->Substitutions to Include : d: Transitions + Transversions
 ->Pattern among Lineages : Same (Homogeneous)
 ->Rates among sites : Uniform rates
 No. of Sites : 642
 No Of Bootstrap Reps = 1000
 Only bootstrap values of 70% and above are shown

*, not a WRLFMD Ref. No.

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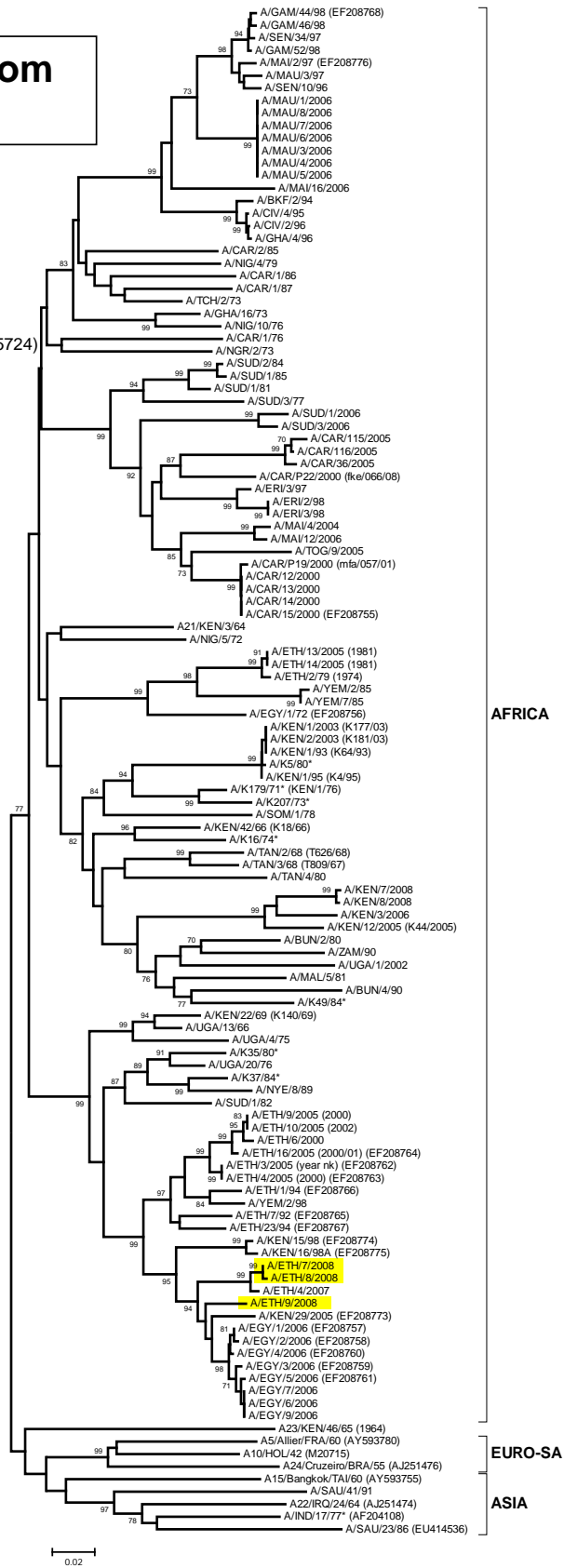


Figure 5. FMDV type A in Ethiopia.

Annex 3. Recent FMD Publications cited by PubMed

1. Paixao TA, Carvalho Neta AV, Paiva NO, Reis JR, Barbosa MS, Serra CV, Silva RR, Beckham TR, Martin BM, Clarke NP, Adams LG, Santos RL. Diagnosis of foot-and mouth disease by real time reverse transcription polymerase chain reaction under field conditions in Brazil. *BMC Vet Res*. 2008 Dec 31;4(1):53. [Epub ahead of print] PMID: 19117507 [PubMed - as supplied by publisher]
2. Zheng H, Tian H, Jin Y, Wu J, Shang Y, Yin S, Liu X, Xie Q. Development of a hamster kidney cell line expressing stably T7 RNA polymerase using retroviral gene transfer technology for efficient rescue of infectious foot-and-mouth disease virus. *J Virol Methods*. 2008 Dec 30. [Epub ahead of print] PMID: 19095010 [PubMed - as supplied by publisher]
3. Dory D, Rémond M, Béven V, Cariollet R, Backovic M, Zientara S, Jestin A. Pseudorabies virus glycoprotein B can be used to carry foot and mouth disease antigens in DNA vaccination of pigs. *Antiviral Res*. 2008 Dec 25. [Epub ahead of print] PMID: 19103226 [PubMed - as supplied by publisher]
4. Tully DC, Fares MA. The tale of a modern animal plague: tracing the evolutionary history and determining the time-scale for foot and mouth disease virus. *Virology*. 2008 Dec 20; 382 (2):250-6. Epub 2008 Oct 21. PMID: 18945462 [PubMed - indexed for MEDLINE]
5. Cottam EM, King DP, Wilson A, Paton DJ, Haydon DT. Analysis of Foot-and-mouth disease virus nucleotide sequence variation within naturally infected epithelium. *Virus Res*. 2008 Dec 11. [Epub ahead of print] PMID: 19027805 [PubMed - as supplied by publisher]
6. Pacheco A, de Quinto SL, Ramajo J, Fernández N, Martínez-Salas E. A novel role for Gemin5 in mRNA translation. *Nucleic Acids Res*. 2008 Dec 9. [Epub ahead of print] PMID: 19066202 [PubMed - as supplied by publisher]
7. de Los Santos T, Segundo FD, Zhu J, Koster M, Dias CC, Grubman MJ. A conserved domain in the leader proteinase of foot-and-mouth disease virus is required for proper sub-cellular localization and function. *J Virol*. 2008 Dec 3. [Epub ahead of print] PMID: 19052079 [PubMed - as supplied by publisher]
8. Lv K, Guo Y, Zhang Y, Wang K, Li K, Zhu Y, Sun S. Transient inhibition of foot-and-mouth disease virus replication by siRNAs silencing VP1 protein coding region. *Res Vet Sci*. 2008 Dec 3. [Epub ahead of print] PMID: 19062053 [PubMed - as supplied by publisher]
9. Cooke JN, Westover KM. Serotype-specific differences in antigenic regions of foot-and-mouth disease virus (FMDV): a comprehensive statistical analysis. *Infect Genet Evol*. 2008 Dec;8(6):855-63. Epub 2008 Aug 23. PMID: 18790086 [PubMed - in process]
10. Fukai K, Morioka K, Ohashi S, Yamazoe R, Yoshida K, Sakamoto K. Differentiation of Foot-and-Mouth Disease Virus-Infected Pigs from Vaccinated Pigs using a Western Blotting Assay Based on Baculovirus-Expressed Nonstructural Proteins 2C and 3D. *J Vet Med Sci*. 2008 Dec;70(12):1353-7. PMID: 19122405 [PubMed - in process]
11. Arias A, Arnold JJ, Sierra M, Smidansky ED, Domingo E, Cameron CE. Determinants of RNA-dependent RNA polymerase (in)fidelity revealed by kinetic analysis of the polymerase encoded by a foot-and-mouth disease virus mutant with reduced sensitivity to ribavirin. *J Virol*. 2008 Dec;82(24):12346-55. Epub 2008 Oct 1. PMID: 18829745 [PubMed - indexed for MEDLINE]
12. Wang DM, Zhu JB, Peng M, Zhou P. Induction of a protective antibody response to FMDV in mice following oral immunization with transgenic *Stylosanthes* spp. as a feedstuff additive. *Transgenic Res*. 2008 Dec;17(6):1163-70. Epub 2008 Jul 24. PMID: 18651235 [PubMed - indexed for MEDLINE]
13. Klein J. Understanding the molecular epidemiology of foot-and-mouth-disease virus. *Infect Genet Evol*. 2008 Nov 28. [Epub ahead of print] PMID: 19100342 [PubMed - as supplied by publisher]

14. Harmsen MM, Fijten HP, Dekker A, Eblé PL. Passive immunization of pigs with bispecific llama single-domain antibody fragments against foot-and-mouth disease and porcine immunoglobulin. *Vet Microbiol.* 2008 Nov 25;132(1-2):56-64. Epub 2008 Apr 30. PMID: 18534789 [PubMed - indexed for MEDLINE]
15. Fosgate GT, Tavornpanich S, Hunter D, Pugh R, Sterle JA, Schumann KR, Eberling AJ, Beckham TR, Martin BM, Clarke NP, Adams LG. Diagnostic specificity of a real-time RT-PCR in cattle for foot-and-mouth disease and swine for foot-and-mouth disease and classical swine fever based on non-invasive specimen collection. *Vet Microbiol.* 2008 Nov 25;132(1-2):158-64. Epub 2008 May 21. PMID: 18499360 [PubMed - indexed for MEDLINE]
16. Li J, Liu Y, Liu X, Shang Y, Liu J, An F, Yin H. [Screening and stability of Madin-Darby bovine kidney cell strain co-expressing the capsid precursor protein P1-2A gene and the protease 3C gene of foot-and-mouth disease virus] *Wei Sheng Wu Xue Bao.* 2008 Nov 4;48(11):1520-5. Chinese. PMID: 19149169 [PubMed - in process]
17. Kim SM, Lee KN, Park JY, Ko YJ, Joo YS, Kim HS, Park JH. Therapeutic application of RNA interference against foot-and-mouth disease virus in vitro and in vivo. *Antiviral Res.* 2008 Nov;80(2):178-84. Epub 2008 Jul 2. PMID: 18601955 [PubMed - indexed for MEDLINE]
18. Dechamma HJ, Ashok Kumar C, Nagarajan G, Suryanarayana VV. Processing of multimer FMD virus VP1-2A protein expressed in *E. coli* into monomers. *Indian J Exp Biol.* 2008 Nov;46(11):760-3. PMID: 19090346 [PubMed - in process]
19. Alexandersen S, Wernery U, Nagy P, Frederiksen T, Normann P. Dromedaries (*Camelus dromedarius*) are of low susceptibility to inoculation with foot-and-mouth disease virus serotype O. *J Comp Pathol.* 2008 Nov;139(4):187-93. Epub 2008 Sep 12. PMID: 18789453 [PubMed - in process]
20. Armer H, Moffat K, Wileman T, Belsham GJ, Jackson T, Duprex WP, Ryan M, Monaghan P. Foot-and-mouth disease virus, but not bovine enterovirus, targets the host cell cytoskeleton via the nonstructural protein 3Cpro. *J Virol.* 2008 Nov;82(21):10556-66. Epub 2008 Aug 27. PMID: 18753210 [PubMed - indexed for MEDLINE]
21. Pacheco A, Reigadas S, Martínez-Salas E. Riboproteomic analysis of polypeptides interacting with the internal ribosome-entry site element of foot-and-mouth disease viral RNA. *Proteomics.* 2008 Nov;8(22):4782-90. PMID: 18937254 [PubMed - indexed for MEDLINE]
22. Wang DM, Shen WT, Li XY, Zhou P. [Analysis of the antigenicity of the expression product of fusion antigen epitope genes of FMDV.] *Xi Bao Yu Fen Zi Mian Yi Xue Za Zhi.* 2008 Nov;24(11):1048-50. Chinese. PMID: 18992188 [PubMed - in process]
23. Pena L, Moraes MP, Koster M, Burrage T, Pacheco JM, Segundo FD, Grubman MJ. Delivery of a foot-and-mouth disease virus empty capsid subunit antigen with nonstructural protein 2B improves protection of swine. *Vaccine.* 2008 Oct 23;26(45):5689-99. Epub 2008 Aug 30. PMID: 18762225 [PubMed - indexed for MEDLINE]
24. Summerfield A, Guzylack-Piriou L, Harwood L, McCullough KC. Innate immune responses against foot-and-mouth disease virus: Current understanding and future directions. *Vet Immunol Immunopathol.* 2008 Oct 17. [Epub ahead of print] PMID: 19026453 [PubMed - as supplied by publisher]
25. Pacheco JM, Arzt J, Rodriguez LL. Early events in the pathogenesis of foot-and-mouth disease in cattle after controlled aerosol exposure. *Vet J.* 2008 Oct 16. [Epub ahead of print] PMID: 18930417 [PubMed - as supplied by publisher]
26. Mohan MS, Gajendragad MR, Kishore S, Chockalingam AK, Suryanarayana VV, Gopalakrishna S, Singh N. Enhanced mucosal immune response in cattle persistently infected with foot-and-mouth disease virus. *Vet Immunol Immunopathol.* 2008 Oct 15;125(3-4):337-43. Epub 2008 Jun 12. PMID: 18656268 [PubMed - indexed for MEDLINE]
27. Agudo R, Arias A, Pariente N, Perales C, Escarmís C, Jorge A, Marina A, Domingo E.

28. Molecular characterization of a dual inhibitory and mutagenic activity of 5-fluorouridine triphosphate on viral RNA synthesis. Implications for lethal mutagenesis. *J Mol Biol.* 2008 Oct 10;382(3):652-66. Epub 2008 Jul 17. PMID: 18662697 [PubMed - indexed for MEDLINE]
29. Rosas MF, Vieira YA, Postigo R, Martín-Acebes MA, Armas-Portela R, Martínez-Salas E, Sobrino F. Susceptibility to viral infection is enhanced by stable expression of 3A or 3AB proteins from foot-and-mouth disease virus. *Virology.* 2008 Oct 10;380(1):34-45. Epub 2008 Aug 9. PMID: 18694581 [PubMed - indexed for MEDLINE]
30. Yang B, Lan X, Li X, Yin X, Li B, Han X, Li Y, Zhang Z, Liu J. A novel bi-functional DNA vaccine expressing VP1 protein and producing antisense RNA targeted to 5'UTR of foot-and-mouth disease virus can induce both rapid inhibitory effect and specific immune response in mice. *Vaccine.* 2008 Oct 9;26(43):5477-83. Epub 2008 Aug 9. PMID: 18694793 [PubMed - indexed for MEDLINE]
31. Golde WT, Nfon CK, Toka FN. Immune evasion during foot-and-mouth disease virus infection of swine. *Immunol Rev.* 2008 Oct;225:85-95. Review. PMID: 18837777 [PubMed - in process]
32. Gutiérrez-Rivas M, Pulido MR, Baranowski E, Sobrino F, Sáiz M. Tolerance to mutations in the foot-and-mouth disease virus integrin-binding RGD region is different in cultured cells and in vivo and depends on the capsid sequence context. *J Gen Virol.* 2008 Oct;89(Pt 10):2531-9. PMID: 18796722 [PubMed - indexed for MEDLINE]
33. Lenhoff RJ, Naraghi-Arani P, Thissen JB, Olivas J, Carillo AC, Chinn C, Rasmussen M, Messenger SM, Suer LD, Smith SM, Tammero LF, Vitalis EA, Slezak TR, Hullinger PJ, Hindson BJ, Hietala SK, Crossley BM, McBride MT. Multiplexed molecular assay for rapid exclusion of foot-and-mouth disease. *J Virol Methods.* 2008 Oct;153(1):61-9. Epub 2008 Jul 25. PMID: 18634827 [PubMed - indexed for MEDLINE]
34. Kittelberger R, Mackereth GF, Sewell M, Keall J, Clough R, Pigott C, O'Keefe JS. Specificity of non-structural protein enzyme-linked immunosorbent assays for the detection of serum antibodies against foot-and-mouth disease virus in a target population in New Zealand. *N Z Vet J.* 2008 Oct;56(5):227-32. PMID: 18836503 [PubMed - indexed for MEDLINE]
35. Veerasami M, Singanallur NB, Thirumeni N, Rana SK, Shanmugham R, Ponselaran S, Muthukrishnan M, Villuppanoor SA. Serotyping of foot-and-mouth disease virus by antigen capture-ELISA using monoclonal antibodies and chicken IgY. *New Microbiol.* 2008 Oct;31(4):549-54. PMID: 19123312 [PubMed - in process]
36. Gao SD, Chang HY, DU JZ, Wang JF, Zhou JH, Zhao JY, Xie QG. [Preparation and characterization of the polyclonal antibody against pig integrin beta6 subunit LBD as FMDV receptor.] *Xi Bao Yu Fen Zi Mian Yi Xue Za Zhi.* 2008 Oct;24(10):975-8. Chinese. PMID: 18845083 [PubMed - in process]
37. Nuanualsuwan S, Thongtha P, Kamolsiripichaiporn S, Subharat S. UV inactivation and model of UV inactivation of foot-and-mouth disease viruses in suspension. *Int J Food Microbiol.* 2008 Sep 30;127(1-2):84-90. Epub 2008 Jun 18. PMID: 18625534 [PubMed - indexed for MEDLINE]
38. Joyappa DH, Sasi S, Ashok KC, Reddy GR, Suryanarayana VV. The plasmid constructs producing shRNA corresponding to the conserved 3D polymerase of Foot and Mouth Disease virus protects guinea pigs against challenge virus. *Vet Res Commun.* 2008 Sep 23. [Epub ahead of print] PMID: 18810649 [PubMed - as supplied by publisher]
39. Wang X, Zhang X, Kang Y, Jin H, Du X, Zhao G, Yu Y, Li J, Su B, Huang C, Wang B. Interleukin-15 enhance DNA vaccine elicited mucosal and systemic immunity against foot and mouth disease virus. *Vaccine.* 2008 Sep 19;26(40):5135-44. Epub 2008 May 6. PMID: 18462848 [PubMed - indexed for MEDLINE]
40. Su B, Wang J, Wang X, Jin H, Zhao G, Ding Z, Kang Y, Wang B. The effects of IL-6 and TNF-alpha as molecular adjuvants on immune responses to FMDV and maturation of dendritic cells by DNA vaccination. *Vaccine.* 2008 Sep 19;26(40):5111-22. Epub 2008 Apr 21. PMID: 18462845 [PubMed - indexed for MEDLINE]

41. Martínez-Azorín F, Remacha M, Martínez-Salas E, Ballesta JP. Internal translation initiation on the foot-and-mouth disease virus IRES is affected by ribosomal stalk conformation. *FEBS Lett.* 2008 Sep 3;582(20):3029-32. Epub 2008 Aug 7. PMID: 18675807 [PubMed - indexed for MEDLINE]
42. Lu H, Huo X, Zhang Y, Zheng M, Ma M, Zhang H, Jin M, Shen G, Jia L, Ji Y, Li X, Jin K, Jin N. Enhancing effects of the chemical adjuvant levamisole on the DNA vaccine pVIR-P12A-IL18-3C. *Microbiol Immunol.* 2008 Sep;52(9):440-6. PMID: 19039952 [PubMed - indexed for MEDLINE]

Annex 4. RECOMMENDATIONS FROM THE WRL ON FMD VIRUS STRAINS TO BE INCLUDED IN FMDV ANTIGEN BANKS – December 2008

High Priority

O Manisa (*covers panasian topotype*)
O BFS or Campos
A24 Cruzeiro
Asia 1 Shamir
A22 Iraq
SAT 2 Saudi Arabia (*or equivalent*)
(not in order of importance)

Medium Priority

A Eritrea
A Iran '96
SAT 2 Zimbabwe
A Iran 87 or A Saudi Arabia 23/86 (*or equivalent*)
SAT 1 South Africa
A Malaysia 97 (*or Thai equivalent such as A/NPT/TAI/86*)
A Argentina 2001
O Taiwan 97 (*pig-adapted strain or Philippine equivalent*)
A Iran '99 (not in order of importance)

Low Priority

A15 Bangkok related strain
A87 Argentina related strain
C Noville
SAT 2 Kenya
SAT 1 Kenya
SAT 3 Zimbabwe
A Kenya (not in order of importance)