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European Commission for the Control of Foot-and-Mouth disease

Digitalization and innovation applied to the prevention and control of Foot-and-mouth And Similar Transboundary animal diseases

Open session of the European Commission for the Control of Foot-and-mouth Disease Standing Technical Committee.

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Report

OPEN SESSION OF THE STANDING TECHNICAL COMMITTEE OF THE EUFMD

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Digitalization and innovation applied to the prevention and control of foot-and-mouth and similar transboundary animal diseases

2022

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
European Commission for the control of Foot-and-Mouth Disease (EuFMD)
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FOREWORD

"Foot-and-mouth And Similar Transboundary (FAST) animal diseases pose a substantial threat to disease-free countries, where single incursions can have devastating outcomes, while controlling them in endemic areas can generate positive effects for national economies, livelihoods of livestock keepers, and animal welfare. Surveillance and control programmes are often expensive and logistically challenging. In this context, developing integrated programmes targeting FAST diseases with similar characteristics might improve use of resources, capacities and accelerate the achievement of animal health targets.

Like many other sectors, veterinary services are experiencing a process of digital transformation characterized by the integration of new approaches, policies and technologies into every aspect of disease surveillance and control. The COVID-19 pandemic has accelerated this trend: animal health professionals have to overcome many challenges, including travel restrictions and shortage of resources. This requires the use of new technologies and the application of creative strategies to reach stakeholders and achieve objectives in the most efficient way.

- How is digital transformation improving FAST capacity building, diagnostics, surveillance, and risk assessment?
- What cultural shifts, processes, and new technologies are changing the way in which we understand and control FAST diseases?
- What opportunities do new technologies contribute to improved FAST surveillance and control?

Research and innovation, digital tools and partnerships between public and private stakeholders in the veterinary domain can improve the control of FAST diseases and contribute to FAO's Strategic Framework in support of the 2030 Agenda through the transformation to more efficient, inclusive, resilient and sustainable agrifood systems for better production, better nutrition, a better environment, and a better life.

The EuFMD Open Session 2022 (OS22) will explore challenges and opportunities offered by digital transformation, innovation, and partnerships in the fight against FAST diseases."

Fabrizio Rolo

ACRONYMS AND ABBREVIATIONS

AESOP	Assured Emergency Supply Option
AMC	Advanced market commitments
ANSES	French National Sanitary Agency
AU-IBAR	African Union – Interafrican Bureau for Animal Resources
CEPI	Coalition for Endemic Preparedness Innovations
CPD	Continuous professional development
DEFRA	Department for Environment Food & Rural Affairs, UK
EC	European Commission
ECDC	European Centre for Disease Prevention and Control
EuFMD	European Commission for the Control of Foot-and-Mouth Disease
FAST	Foot-and-mouth and similar transboundary
FAIR	findable, accessible, interoperable and reusable
FAO	Food and Agriculture Organization of the United Nations
FMD	Foot-and-mouth disease
FMDV	Foot-and-mouth disease virus
GAVI	The Vaccine Alliance
GMO	Genetically modified organisms
GP	Goat pox
LFD	Lateral flow device
LMIC	Low- and middle-income countries
LSDV	Lumpy skin disease virus
LTA	Long-term supply arrangement
MN	Member Nations
MSP	Multistakeholder platform
NGS	Next generation sequencing
OS	Open Session
PPR	Peste des Petits Ruminants
PPRV	Peste des Petits Ruminants virus
PCP	Progressive control pathway
PCR	Polymerase Chain Reaction
QMRA	Quantitative Microbial Risk Assessment
RNA	Ribonucleic acid
RRA	Rapid risk assessment
RVF	Rift Valley Fever
SCSAR	Special Committee for Surveillance and Applied Research
SCBRM	Special Committee on Biorisk Management
SCRPD	Special Committee for Research and Programme Development
SEACFMD	Southeast Asia, China and Mongolia Foot-and-Mouth Disease
SP	Sheep pox
STC	Standing Technical Committee
SVA	Swedish National Veterinary Institute (Swedish: Statens veterinärmedicinska anstalt)
TADs	Transboundary animal diseases
VADEMOS	Vaccine Demand Estimation Model for FMD
VEOCS	Virtual Emergency Operations Centres
WOAH	World Organisation for Animal Health
WOAH WAHIS	World Animal Health Information System of the WOAH
WHO	World Health Organization
WRL-FMD	World Reference Laboratory for FMD

THE OPEN SESSION 2022

The Open Session (OS) of the Standing Technical Committee of the European Commission for the Control of Foot-and-Mouth Disease (EuFMD) is held every two years and has become the largest technical and scientific meeting on foot-and-Mouth and similar transboundary (FAST) animal diseases to be convened on a regular basis.

The EuFMD has organized these meetings since the early 1970s, alternating a closed session with an open one to increase scientific exchange.

In October 2022, the EuFMD organized a three-day hybrid scientific conference, in Marseille, France. Eighty-eight abstracts were submitted to the scientific committee, reviewed and clustered into the six main technical sessions. Fifty-six presenters were invited to showcase their work, including 16 keynotes presenters, and participate in 12 panel discussions. Two workshops were held in addition to the plenary sessions, and the reports are the appendices at the end of this report. Overall, 150 participants attended the OS22 in person, while more than 600 colleagues worldwide were given the opportunity to attend the conference online (streaming on YouTube®: day 1; day 2 and day 3), give presentations and interact with the panellists through an online forum.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS FROM THE OPEN SESSION 2022

Session I: emergency preparedness and response

Conclusions

- The functionality of virtual emergency operations centres is not simply about moving existing tools and processes online but about redefining tools and processes for a virtual environment. Guidance, in the form of protocols, should be adapted to the current situation and made available to stakeholders to assist them to adapt to the virtual environment.
- Although challenging, technology can assist with managing virtual response, response coordination and decision-making. However, further improvements are needed to address the needs of emergency response.
- Modelling for contingency planning should be built and used in peacetime based on reliable and high-quality data to prepare for an outbreak. Modelling can, to a lesser extent, facilitate decision-making by incorporating real-time data in a real-time situation.
- A change of approach is needed in order to use modelling to respond to the expectations of politicians and stakeholders expecting real-time information and actions. Models need to provide confidence and evidence for proper decision-making of the selected strategy of response.
- Different models will be better in different situations depending on the availability of data and what questions are to be addressed.
- Models can allow comparison of different control options in a number of scenarios.
- Multidisciplinary approaches, putting together epidemiological and economic studies, social considerations and environmental constraints could improve the outputs of predictive modelling.
- Technologies can assist with technical decision-making, but other factors (social, economic, ethical, etc.) must support decision-making as well.

Recommendations

- Virtual emergency operations centres can incorporate many of the processes involved in physical centres, but challenges persist with user adaptation to the virtual environment, efficient information exchange and situational awareness.
- A community of practice could be established and improved to facilitate the exchange of methodologies that are being developed or innovated, implemented, the results and the way results are communicated to the policy makers. This would support possible complementarity of different models.

Session II : digital learning

Conclusions

- The COVID-19 pandemic heightened the focus on digital and online education to unprecedented levels, encouraging both educational providers and industries to work on new strategies to use and embed digital technologies and online education into working practice and training.
- Examples of digital tools currently in use in veterinary education are virtual learning environments, videoconferencing tools, video casting (live-streamed and recorded content), and mobile technologies (e.g. apps with bite-sized exercises), with a particular attention to the level of interactivity that these tools can offer. These tools can operate thanks to a set of innovative technologies that include artificial intelligence (chatbots, natural language processing, machine learning), virtual/augmented reality technology, and learner analytics.
- Artificial intelligence, microfluidics, and point-of-care molecular diagnostics are the basis for important developments in veterinary diagnostics; real-time monitoring of health in animals improved thanks to the advancements in sensors and smart tags; finally, artificial intelligence and machine learning are making it possible to exploit the data deriving from monitoring and diagnostic activities to identify behaviour changes and risk factors for disease.
- Digital training can have a positive impact on the education of veterinarians and veterinary paraprofessionals by ensuring equitable and cost-effective access to high-quality resources. This can be especially true for animal health workers located in remote areas or facing sudden animal health emergencies.
- New technologies can offer cost-effective, scalable tools for animal health emergency training and response purposes.

Recommendations

- The main challenge for the process of digital transformation of the training field is not the development of new technologies but rather the evolution of teaching, learning, and assessment approaches. Rather than focusing on facts and notions, assessments of online training should ask the trainees to apply the knowledge acquired and discuss it critically.
- Inclusiveness (access to technology and gender aspects, for instance) should be always considered when designing digital training. Most important technologies for FAST diseases include hardware (portable electronic devices), reliable connectivity, and technical skills. To promote the digital transformation of the animal health sector, it is paramount to ensure equitable access to digital infrastructures and proper acquisition of basic digital skills for all trainees and workers, including those located in remote or underdeveloped areas. This will prevent the creation of a generational or societal gap in the veterinary workforce.
- Accreditation of training programmes must evolve in parallel with the new technologies that are being employed. Training providers need to develop internal and external standardized quality assurance schemes and ensure accreditation of digital training to enable the recognition of competencies for academic and employment purposes.
- Virtual reality and digital technologies in general are not meant to replace face-to-face or practical activities, but rather to complete them by offering additional tools and solutions to make the learning experience more accessible, active and engaging.
- The idea of combining formal and informal training using “digital badges” or “microcredentials” is an interesting approach for improving animal health training.
- It might be useful to explore whether social learning (learning from and with each other) would be possible online or if instead it would require a blended learning approach.
- The Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (WOAH) showed enthusiasm about learning and innovation: it will be important for these international organizations to collaborate with universities which are specialized in education. It is important to work in partnership to improve future learning and avoid duplications.

Session III: virology and diagnostics

Conclusions

- The importance of investing in research and developing and maintaining a dialogue between the public and private sectors to ensure the application of new research outcomes was highlighted.
- It was concluded, on the issue of virus host interaction, that antivirals' development is still far from the field application of antivirals.
- New technologies, for virus host interaction, are scientifically interesting, but it should be acknowledged that most of these new technologies may end up in the *Valley of Death*, i.e. will not be applied as routine diagnostic tools. It is of utmost importance to design diagnostic technologies that meet the needs of field vets and farmers, and therefore also to connect as early as possible with the industry to optimize the chances to get new technologies to the market.
- A first line test, which should be low cost, is needed for immediate control measures to be put in place; however, real-time Polymerase Chain Reaction (PCR) is relatively expensive regarding instruments and reagents needed; therefore, conventional PCR can be more feasible for some endemic countries.
- Lateral flow devices (LFD) that are more affordable in the field should be validated for endemic countries and made available at a low price.
- To reduce the risk, the test should be as generic as possible for many FAST diseases; deploying sequencing and diagnostic capabilities for a wide range of diseases is the approach forward and contributes to the sustainability.
- The first step is early detection based on clinical signs; first samples do not need high tech methods, and multidisease sampling should be the way forward.
- Sequencing is getting cheaper and provides a great opportunity to be used in connection with other epidemiological data that are needed for successful control plans.
- Not properly inactivated LFD and samples sent to laboratories located in FMD-free countries may pose a risk; laboratories receiving samples need to be authorized by foot-and-mouth disease virus (FMDV) labs; small amounts of ribonucleic acid (RNA) could be taken up (molecular samples are in principle safe, although intact FMDV RNA can induce foot-and-mouth disease (FMD) upon infection and so-called infectious genomic material is forbidden in some countries [legal aspect]).
- FMDV is not zoonotic, but there are some anecdotal reports (i.e. If you take human cells and infect them with high dose of viruses, you may get infected).

Recommendations

- Carefully consider the Special Committee on Biorisk Management (SCBRM) recommendation regarding the safety of shipment of inactivated LFDs. Inactivation protocol needs to be followed prudently, and there is a risk that the message of shipment of LFD may not be received properly, increasing the risk that LFD may not be validated for shipment or may not adequately be inactivated before shipment, exposing laboratories to FMDV contamination with LFDs acting as fomites.
- Environmental sampling, and wastewater and milk sampling should be considered as approaches when looking for the presence of virus.
- Clinical diagnosis should still be considered the first point of diagnosis as it is already a valuable tool, and diagnostic tests might be expensive in certain settings.

Session IV: vaccinology

Conclusions

- Innovative vaccine platform technologies have many advantages over conventional vaccines including their potential for accelerated development and rapid modification to include new vaccine strains in the event of emerging field strains for hypervariable viruses.
- Innovative technology platforms do not require the handling of large quantities of live pathogens and therefore industrial manufacture does not require high-containment facilities, thereby reducing costs and the risks associated with handling live infectious pathogens.
- Basic immunological research and structural vaccinology are key to understanding the protective determinants and to engineering antigens when developing novel vaccines with improved efficacy and effectiveness.
- There continue to be opportunities for industry, academia and regulators to work closely together to optimize product development and improve the time to market. Novel technologies present unique challenges to ensuring safety, not only for target animals but also for consumers of meat and dairy products from vaccinated food-producing animals, and potentially to the environment, for vaccines which are classified as genetically modified organisms (GMOs).
- A system for prequalification of FAST vaccines can promote the use of high-quality FAST vaccines that meet at least minimum international standards. Linking a prequalification system to procurement through long-term supply arrangements (LTA) and/or assured emergency supply options (AESOP) should enhance the availability of FAST vaccines by creating a sustainable and more predictable environment in which manufacturers can invest in their development and production capacity.
- The Nagoya Protocol was designed to ensure fair and equitable sharing of benefits arising out of the utilization of genetic resources, thereby contributing to the conservation and sustainable use of biodiversity. However, its application to infectious pathogens has resulted in difficulties for vaccine manufacturers to access microorganisms or genetic sequences that could lead to important new strains to combat evolving pathogens.
- Smart farming technologies can support farmers and veterinarians to improve the health and welfare of animals by time-optimized surveillance, improved monitoring and rapid detection and management of disease outbreaks.
- More work can be done to optimize vaccine potency and immunogenicity testing for FMD vaccines and for routine batch testing, especially in consideration of the principles of the 3Rs (Replacement, Reduction and Refinement). Industry, academia, regulators and those organizations responsible for setting standards for vaccine testing should work more together to identify test methods that replace the use of animals where possible or reduce their numbers and the severity of the experiments. Progress in *in vitro* tests and the “consistency approach” to manufacture can support a reduction in animal usage.

Recommendations

- The veterinary scientific community, national animal health agencies and international organizations need to come together to develop an innovative framework for FAST animal pathogens within the scope of the Nagoya Protocol to provide for rapid access to new pathogens and sequences for vaccine development, whilst ensuing fair and equitable sharing of the benefits.
- A review, bringing together industry, academic and regulatory experts, of the international standards for immunogenicity and potency testing of FMD vaccines should be conducted to identify improvements in ensuring the quality of FMD vaccines that takes into account scientific and technical developments in *in vitro* tests and the need to integrate the principles of the 3Rs.
- A system for linking the prequalification of FAST vaccines to procurement through long-term supply arrangements (LTA) and/or assured emergency supply options (AESOP) should, be

developed to improve the capacity and availability of high-quality vaccines.

- A forum to identify regulatory issues for innovative vaccine technologies for FAST diseases could help ensure that industry is able to undertake the necessary studies and risk assessments during development to minimize delays to authorization and marketing.

Session V: risk assessment and modelling

Conclusions

- Modellers have to ensure the interplay between data, models and knowledge in a cyclic process of improvement. Modelling is affected by diversity of data types and sources, geographic and temporal scales, quality of records, data owners and managers. Several integrated data systems do exist nowadays that try to address this diversity, define the better modelling solutions, and provide the best answers based on the information available.
- Integrated data systems enable the automatic visualization of data, improve operationalization of information, and improve communication with stakeholders. Integrated data systems should be designed following the FAIR principle: they should be Findable, Accessible, Interoperable and Reusable (FAIR). However, developing a FAIR database is expensive and time consuming. Data tend to change with time (due to changes in livestock industries, monitoring and reporting, and collection strategies), and this makes it important to ensure traceability of inputs with the outputs with integrated data systems.
- Cloud computing offers interesting opportunities, but it is important to evaluate pros and cons. It greatly facilitates communication and ownership in data collection but costs, sustainability of the infrastructure, location of servers and legal environment should be considered carefully.
- Current modelling is addressing new research questions:
    - At the global level, studies are being carried out to quantify the current geographic extent of animal diseases and predict potential changes in their distribution in the next decades.
    - At a more local level, models are being used to understand the role of animal movements in relation to disease dynamics and potential targeted control actions. Furthermore, modelling multiple diseases with the same model can offer the possibility to assess the impact of measures capable of preventing different diseases at the same time.
    - Models can also explore the social, economic and equity components. Recent modelling research encompassed epidemic recovery, optimal allocation of resources (diagnostic kits, vaccine doses), and social aspects (population sentiment analysis, individual risk perception and misinformation and their effects on disease dynamics, new approaches to inequality in infection risk).

Recommendations

- To be able to inform policy effectively, modellers should build relationships with partners, industries, government agencies and state animal health officials. This would enable them to be part of the conversation, understand the complexity of the broader context, be trusted, and find the strategic moment at which modelling results can be brought to the table to help inform the debate. Questions should always come first and orient the analysis and modelling efforts, and not vice versa. It is important to focus on sustainable systems with adequate pipelines for data collection and analysis, research partnerships and model development.
- Models can support decision-making in the event of an outbreak. However, during the initial phase of an outbreak, model outputs are often characterized by significant uncertainty due to the lack of data. The uncertainty resolves as more data become available. Modellers must

communicate this uncertainty properly and ensure that the models are parameterized based on the most up-to-date information available. Models' outcomes should therefore form only part of the evidence employed to define disease control policies.

Session VI: surveillance and control

Conclusions

- The SARS-CoV-2 pandemic has come with a wide range of new approaches to COVID-19 surveillance and control which should also benefit FAST risk reduction. These include:
    - wastewater/environmental sampling as a means to monitor viral prevalence at population scale;
    - demonstrated international modalities to bring new vaccines into use in a short time; role of advanced market commitments (AMC), and multistakeholder platforms (UN, private sector, vaccine alliances like The Vaccine Alliance (GAVI) and the Coalition for Endemic Preparedness Innovations (CEPI), investment management);
    - scaling up sequencing for real-time tracking;
    - global network of sequencing centres, with new strategies for use in variant tracking and health care workers in front line positions; and
    - virtual learning to support rapid scale up of trained medical and health care workers in front line positions.
- To improve disease risk mitigation and increase its sustainability, market-driven approaches are increasingly used where the interests of improved production and disease risk management align. Powerful information technology, effective business models and strong data governance are prerequisites for successful implementation of such approaches.
- Environmental FMD sampling can be used when no outbreaks are reported. More research would be needed to determine if environmental sampling of FAST diseases could be used as a means of early detection of an affected location (i.e. prior to clinical onset).
- EuFMD and FAO will continue to support countries and regions which are seen as beacons for the progress in FAST risk reduction in wider regions. During the session, the example of Georgia and its progress to progressive control pathway (PCP) stage 3 was highlighted.
- FMD serotype C extinction is further verified through combining data temporally and spatially. For each virus pool, expert solicitation will improve the analysis framework to increase confidence that serotype C is extinct.
- The use of novel animal health surveillance data collection for FAST diseases in the agricultural sector is investigated and already employed in FMD endemic and free countries on both farm and wider surveillance levels. These technologies include the use of drones, sensors and thermal imaging.
- With *OpenFMD*, the Pirbright Institute offers a data sharing and analytical portal to enhance genomic and epidemiological surveillance of FMD. The tool will improve timely analysis and communication of FMD data, identification of surveillance gaps and emerging disease trends to support evidence-based decision-making processes for FMD control. Another tool presented at this session is based on FMD data collected from Southeast Asia, China and Mongolia Foot-and-Mouth Disease (SEACFMD) members. It allows users to visualize spatial or temporal trends of FMD and circulating FMD virus strains which will enhance early warning and response.
- As also concluded in the two keynote papers, animal health policies need to be accepted by the farmers and other stakeholders to be successful. This was underlined by a field study from Kenya which demonstrated that although FMD vaccination was economically beneficial to farmers, barriers in the acceptance of FMD control were present, including uncertainty in costs associated with an FMD outbreak, challenges in disease control coordination and unclear relationships between farmers and animal health service providers.
- A vast range of novel techniques and approaches for surveillance and control have been developed and are available. The main challenge is the smart use of these techniques in the field to effectively contribute to the health of livestock and to improved delivery of both the veterinary services

authorities and private animal health service providers.

Recommendations

- The collaboration between FAO, WOAH and the World Health Organization (WHO) needs to be intensified to share responsibilities and coordinate global activities to address health risks at the animal-human-ecosystems' interfaces. Both the animal and human health sectors will benefit from the mutual exchange of knowledge, experience and tools in the management of animal and human disease emergencies.
- To increase the sensitivity of a surveillance system, consider the increased use of novel approaches for surveillance and data collection, like global and regional data exchange platforms and vaccine alliances, market-driven disease detection approaches, 24/7 surveillance, and drone, sensor and environmental sampling.
- To improve FAST surveillance and control cross-cutting approaches between diseases as well as country and region-specific approaches, more attention should be given.

OPENING CEREMONY

Lajos Bognar, Chief Veterinary Officer (CVO) of Hungary and President of the EuFMD Executive Committee, formally opened the ceremony. He welcomed the EuFMD support for the preparedness and control of FMD and other similar transboundary (FAST) animal diseases, as EuFMD commits to disseminating the most up-to-date information and knowledge on FAST to support the work of veterinarians in Member Nations (MNs) to fulfil their duties and responsibilities. He welcomed the numerous specialists providing technical presentations at the OS22 and called for the new technologies presented to have significant impact on the quality of the work of veterinarians in relation to these diseases.

Jean-Luc Angot, Head of the French Board of Inspectors of Veterinary Public Health and former chairperson of EuFMD, representing Mme Soubeyran, the French Chief Veterinary Officer, started by acknowledging the activities of the EuFMD that provides Members Nations and neighbouring countries with rich, diversified and continuously expanding technical assistance. He mentioned the remarkable evolution of the EuFMD in the fields of training and the constitution of efficient and dynamic networks in several languages. The expertise of the EuFMD is recognized worldwide, and the EuFMD is now responding to requests arising from veterinary authorities in Asia, Oceania and the Americas. France is part of the EuFMD Executive Committee since 2009 and held the presidency and vice-presidency until 2021. Every year, France contributes to the EuFMD and strives to mobilize the best of its expertise notably in the Special Committee for Research and Programme Development (SCRPD). Jean-Luc Angot took this opportunity to acknowledge the involvement and determination of Stephan Zientara as Chair of the Standing Technical Committee (STC) and the expertise of the French National Sanitary Agency (ANSES), recognized as one of the major players in international research in relation to public decision-making. Considering the recent sanitary crisis, structures like the EuFMD are essential. He further highlighted that FMD is far from being a disease from the past. Emerging and re-emerging threats continue to capture the MNs' attention, and these events call for the promotion and adoption of the *One Health* approach. To face sanitary dangers, the principal *prevention is better than cure* is essential; however, it requires good coordination between public and private actors as well as the implementation of effective prevention mechanisms based on training, surveillance, biosecurity and good governance. The EuFMD is contributing to the achievement of clear results in these areas. This is why the European Commission and other donors give their confidence in the EuFMD in the fight against other transboundary animal diseases. Jean-Luc Angot stated that France will continue to support the EuFMD and stressed the major importance of networks to react and interact rapidly at all levels to disease emergence and re-emergence.

Stephan Zientara, Chairperson of the EuFMD STC, reviewed the roles of the STC to identify issues affecting FAST management that need to be brought to the agenda of the Commission Sessions and to the MNs, to contribute to identifying topics and selecting studies and tools useful for risk managers and to oversee the plans and activities of the two special committees on Surveillance and Applied Research (SCSAR) and on Biorisk management (SCBRM). Food-and-mouth disease remains the main focus of the EuFMD, continues to be a serious threat to Europe and is currently at the doorstep of the European Union (EU). The OS22 is a major event in the EuFMD activities and one of the only events to bring together Health authorities, policy makers and scientists. The EuFMD has always emphasized the importance of global surveillance of FAST disease virus intelligence to inform risk monitoring and preparedness. Stephan Zientara acknowledged the remarkable work conducted by the EuFMD team, especially during the COVID-19 pandemic, and the commitment and availability of Fabrizio Rosso, the EuFMD Deputy Executive Secretary.

Fabrizio Rosso stressed that innovation and digitalization is a particularly relevant issue to bring together

researchers and policymakers. This conference is expected to provide evidence of applied research results, making them available to decision-makers and risk managers, and allow discussions on results. He outlined that the first OS was held in 1997 in Ankara with a wide representation of laboratories and institutes around the globe and was called the *Meeting of the Research Group of the Standing Technical Committee*. Topics discussed at that time were the evaluation of potency of vaccines, the duration of immunity in sheep after inoculation and the correlation of virus strains detected in Europe and the Near East. He hoped that during this three-day OS22, the audience would be able to interact regarding what cultural shifts, technologies and innovative solutions could help the whole community better understand the best way to control FAST diseases. He thanked the entire EuFMD team organizing this event, the STC for the technical oversight and scientific inputs provided to the Secretariat and the Commission, Keith Sumption, and Martin Blake, the former chair of the Commission, for his constant support.

FAST UPDATES

Headline events from global foot-and-mouth disease surveillance activities (2020–2022)

Donald King, Head of the Vesicular Disease Reference Laboratory group, the Pirbright Institute, United Kingdom of Great Britain and Northern Ireland

Summary

This presentation provided an overview of FMD surveillance activities since the last EuFMD OS in 2020. These data were collated from the WOAH/FAO FMD Laboratory Network which was established in 2004 as a forum to exchange laboratory and epidemiology data on FMD, as well as to harmonize and improve the quality of diagnostic testing carried out by international and national FMD laboratories. A key role of the network is to monitor the spread of viral lineages that are maintained in the seven endemic pools distributed across the world and review the risks to livestock industries in countries that are free of FMD (with or without vaccination). These global surveillance activities show that serotype O is the most frequently detected FMDV serotype, followed by serotype A. Furthermore, these data highlight important surveillance gaps across the endemic pools (such as in West Africa) and also motivate the work undertaken to improve the quality of sample submissions to the network since ~40 percent of samples submitted to the network fail to yield FMDV-specific data. In addition to continuous circulation of the pool-specific viruses, long-distance trans-pool movement of FMD viral lineages has been a common theme of recent reports generated by laboratories within the network.

Since the last OS in 2020, particular attention has been focused on the continued expansion of the O/ME-SA/Ind-2001e lineage which has become the dominant serotype O virus in Southeast Asia supplanting other lineages that were previously present (O/SEA/Mya-98 and O/ME-SA/Pan Asia) and from where onward spread has caused extensive outbreaks on the Islands of Indonesia, a country that had previously maintained an FMD-free (without vaccination) status since 1990. Cases due to this lineage, which are most closely related to viruses collected in Mongolia highlighting a new risk pathway for central Asian countries north of the Himalaya, were also documented in Kazakhstan and the Russian Federation (during 2021–22). In the European neighbourhood, FMD outbreaks occurring in the Eastern Mediterranean (Jordan, Israel and Palestine) have been caused by viruses from a new genetic clade within the O/ME-SA/PanAsia-2^{ANT-10} sublineage, while in North Africa (Tunisia and Algeria), there have been new field outbreaks due to the O/EA-3 topotype which are most closely related to viruses collected in West Africa. The emergence of FMD in the Maghreb is a significant change of epidemiological status which may substantiate new trans-Saharan connections between North and West Africa (Pool 5). Elsewhere, the O/EA-2 topotype has spread into Southern Africa (Pool 6), where cases in Zambia, Namibia, Malawi and Mozambique represent the first time that this serotype has been detected in the region since 2000, when a virus of Asian origin (O/ME-SA/Pan Asia) caused an outbreak in South Africa. This incursion poses a new threat for the Southern Africa region, and the potential onward spread of O/EA-2 will now need to be closely monitored since serotype O vaccines are not widely used in Namibia, nor in neighbouring countries. The presentation also described the situation in Egypt where there have been recent reports of FMD cases due to serotype O and A viruses from the O/EURO-SA and A/EURO/SA topotypes. These unexpected events represent the introduction of completely new viral lineages from South America into North Africa and raise many questions regarding the routes by which these viruses have transited across the Atlantic, as well as the potential for these lineages to become established and spread in the region.

In summary, the presentation highlights the ease by which FMDV can cross international boundaries and emphasizes the importance of the work undertaken by the WOAH/FAO FMD Reference Laboratory Network to continuously monitor the global epidemiology of FMD and to assess the suitability of FMD vaccines to control outbreaks caused by these diverse viruses. Initiatives are underway to re-engage with field and labs teams in endemic countries to improve surveillance activities which have been impacted by the COVID-19 pandemic. Further published information include the individual laboratory reports from the following website (http://www.wrlfmd.org/) as well as quarterly reports published in partnership

with EuFMD which summarize FMD events (https://www.wrlfmd.org/ref-lab-reports).

Discussion relates to a better understanding of the risk pathways and likelihoods for the incursion of exotic strains (such as in Egypt and Indonesia, recently) as well as indicators that could help predicting dominant FMDV strains (based on reflections of drivers for emergence and fitness features for SARS-CoV-2 or influenza viruses).

Peste des petits ruminants (PPR) and Rift Valley Fever (RVF) events 2020–2022 and risk of introduction into Europe

Andrea Apolloni, French Agricultural Research Centre for International Development (CIRAD), Unité Mixte de Recherche ASTRE, France (on behalf of Veronique Chevalier)

Summary

The speaker first reviewed the Rift Valley Fever (RVF) epidemiology and history, the global situation 2020–2022, implications on mobility and risk of introduction into Europe, and provided a review of the competence of Mediterranean potential vectors, next steps and work in progress. RVF is nowadays present in almost all sub-Saharan Africa. RVFV spread into new area is achieved by live animal movements (although trade is forbidden between Europe/Maghreb and enzootic countries) and through the introduction (mostly wind-borne and by human transports), and installation of competent vectors. Risk of introduction into Europe exists but is considered low (Nielsen *et al*., 2020). However, there are growing concerns about RVFV spread in the Mediterranean Basin due to the following key factors: (i) the recent emergence of RVFV in Libya (2019–2020), (ii) the serological evidence of viral circulation in Tunisia and western regions of Sahara, as well as (iii) the presence of competent mosquito species (mainly *Aedes caspius, Ae. Detritus, Ae. Vexans, Culex pipiens, Cx. Theileri*; based on a recently published meta-analysis of the competence of Mediterranean potential vectors [Drouin *et al*., 2022]) combined with (iv) uncontrolled live animal trade routes existing from sub-Saharan to North African countries. Further presence of the RVFV in North Africa would increase the risk of introduction into Europe. Modelling of the dynamic of vector population in the Mediterranean basin and transmission to local hosts is ongoing.

Then the speaker addressed Peste des Petits Ruminants (PPR), went through epidemiology and history, the situation in 2020–2022, mobility and risk of introduction into Europe and finally PPR status eradication in Eurasia. He noted that PPR is not an African disease anymore, one billion animals are at risk globally, and several million households are at risk. There are four lineages, and evidence shows that lineage IV tends to replace historical lineages (I and II). PPR eradication is foreseen by 2030, and the Global Eradication Programme identifies the importance of risk-based surveillance and vaccination as the main tools for PPR control. For both, adaptation to the local context is paramount. PPR notifications to WOAH between 2020 and 2022 were presented, acknowledging that the vast majority of reported cases were on domestic species. A rapid analysis of the official trade exchanges from PPR infected areas to Europe extracted from UM Comtrade was presented. Among the most at-risk European countries for Peste des Petits Ruminants virus (PPRV) incursion, Bulgaria was presented as connected to many European countries and as a gateway for introduction of PPRV incursion in Europe; the largest flows of small ruminants recorded in UN Comtrade are between Bulgaria and Romania, and between Bulgaria and Türkiye. Analysis showed that Türkiye is connected to Cyprus and Ireland and that Germany is exposed directly to African countries. However, it should be stressed that reporting data is missing, as well as information on wildlife. There is also the need to consider « All the network » and include non-direct connection into this preliminary analysis. Finally, a review on the PPR epidemiology situation and status of control and eradication in Eurasia was presented (Legnardi *et al.,* 2022), and the following was highlighted: (i) there is a wide PPRV circulation in small ruminant and wildlife populations in the Islamic Republic of Iran, despite vaccination effort; (ii) in Tajikistan, PPR is probably still endemic; (iii) several countries are reported as users of a vaccine that is not Nigeria/75/1 vaccine strain; (iv) several countries

are presented with poor reporting system, and real status unknown (e.g. Turkmenistan, Uzbekistan); (v) there are shortcomings in surveillance and post-vaccination efforts; (vi) there is a lack of awareness campaigns involving stakeholders; and finally (vii) budget allocated to PPR control and eradication is not always adequate.

Key aspects of the current sheep pox, goat pox and lumpy skin disease virus epidemiology, 2020–2022

Nick De Regge, Sciensano, Scientific Direction of infectious diseases in animals, Service exotic and vector-borne diseases, EURL capripox viruses

Summary

Lumpy skin disease (LSD), sheep pox (SP), and goat pox (GP) are notifiable transboundary diseases of cattle, sheep and goats, respectively, caused by viruses of the *Capripoxvirus* genus. They are responsible for direct and indirect financial losses, originating from animal mortality, morbidity (including fever, reduced milk production, characteristic pox lesions, etc.), costs of vaccination, and trade restrictions of animals and their products.

Sheeppox virus (SPPV) and goat pox virus (GTPV) are endemic in many countries in Africa, the Near East and Asia. Incursions in Europe have been limited during the last decades with only a few outbreaks in Greece between 2013 and 2018, and in Bulgaria in 2013.

- Mid-September 2022, an SPPV virus outbreak was reported in the province of Granada, Spain. This was the first notification of SPPV since the virus was eradicated in Spain in 1968.
- By 28 October 2022, outbreaks had been reported on 17 farms: eight in close proximity to the index case in Granada and eight in a second cluster in the province Cuenca, Castilla-La Mancha.
- The exact origin of the virus remains unknown.
- This outbreak in Spain is a reminder that any country can be confronted with the introduction of a FAST disease and that efforts to increase preparedness and awareness need to be maintained.

Lumpy skin disease virus (LSDV) is a vector-borne disease in cattle that has been endemic in large parts of Africa for a long time, and since the beginning of the 2000s has gradually spread through the Near East and Türkiye, into the Balkans, Russia and the Caucasus.

- Since 2019, the disease has been notified in China, Bangladesh and India, and has since then spread over South-eastern Asia at an enormous paste, reaching Indonesia in 2022.
- Full genome sequencing of LSDV strains from outbreaks in South-eastern Asian countries has highlighted that vaccine-like recombinant strains, which were first reported in Russia in 2017, are responsible for the ongoing epidemic.
- Recent data indicate that the recombinant strains are the result of recombination events that occurred during a badly controlled vaccine manufacturing process. The use of this vaccine caused the release of these strains in the field.
- These recombinant LSDV strains behave as wild type strains and cause clinical disease and LSDV outbreaks.
- The recombinant strains undermine available diagnostic testing strategies since they are missed or recognized as vaccine strains by so called DIVA PCRs, which are normally used to discriminate LSDV vaccine strains from wild type field strains.
- Preliminary indications of increased virulence and potential non-vector-borne transmission of the recombinant strains urgently need to be studied in more detail, just as does the efficacy of available vaccines against these strains.
- It will be important to closely monitor the situation in the Near East and India where classical field strains and recombinant field strains will probably circulate together in the near future.

SESSION I: EMERGENCY PREPAREDNESS AND RESPONSE

Chair: Sten Mortensen; **Moderator**: Katherine Gibson; **Co-moderator**: Bouda Vosough Ahmadi

Background

During the COVID-19 pandemic, emergency managers worldwide had to activate their emergency management plans in a virtual environment, and operate, at least partially, from virtual emergency operations centres. What lessons were identified from these experiences? Which parts of the emergency response could be managed virtually, and which still required face-to-face interaction? What systems need to be developed or improved to enable information exchange in the virtual environment? How has the engagement of stakeholders been affected by the use of virtual technology?

Modelling to support contingency planning – Use of models has become essential to evaluate the impact of different response measures to FAST diseases. How can models contribute to improvements in contingency planning? What are the limitations of currently available models and how can they be overcome? How can models be used for real-time response planning? How can remote technology, such as unmanned aerial vehicles (drones), thermal imaging and artificial intelligence contribute to early detection of disease and surveillance in livestock and wildlife?

Objectives

- Explore how digital transformation is supporting emergency preparedness and response.
- Describe how new technologies can assist more efficient information exchange and timely decision-making in a response to an FMD or similar transboundary animal disease incident.
- Explore how technology can support contingency planning while taking into account the broader impacts of response decisions on trade, on animal health and on communities.

Summary

The Chair, Sten Mortensen, opened the morning session, which was moderated by Katherine Gibson. The session comprised two presentations delivered by keynote speakers, six short presentations and two round table plenary discussions. The keynote presentations were given by Carol Dumbeck (Alberta Health Services – Emergency/Disaster Management, Canada) on experiences of virtual emergency operations centres during the COVID-19 pandemic response in Canada and Annette Boklund (University of Copenhagen, Denmark) on new technologies to assist timely decision-making in a response and the use of modelling to support contingency planning. The two keynotes and a presentation by Yuta Himura (Animal Health, Australia) and Stacey Hook (Queensland Government, Department of Agriculture and Fisheries, Australia) on case studies from Australia's biosecurity sector on digitizing preparedness and response completed the topics for the first panel discussion. The specific topics addressed included how can technology assist emergency response and responders when emergency operations centres must operate virtually, support more efficient information exchange during emergency response, especially in the virtual environment, and support real-time decision making.

The second panel discussion was moderated by Bouda Vosough Ahmadi and followed the presentations by Tatiana Marschik (University of Veterinary Medicine, Vienna, Austria) on emergency vaccination as an additional measure to control a potential outbreak of FMD in Austria; Beate Conrady (University of Copenhagen, Denmark) on simulation of FMD spread and mitigation measures in the Danish livestock population; Graeme Garner (EuFMD) on reducing producer losses in an FMD outbreak through implementing trading zones; Giovanna Ciaravino (Universitat Autónoma de Barcelona, Spain) on OUTCOST-RUM, a tool to support countries in the evaluation of the economic impact of transboundary animal diseases (TADs) affecting ruminants; and Edward Hill (University of Warwick, United Kingdom of Great Britain and Northern Ireland) on modelling livestock infectious disease control policy under differing perspectives on vaccination behaviour. The topics addressed during the conversation with panellists covered the use of modelling to assess social, financial, and animal health impacts, the different available approaches to be used together to give a holistic approach to decision-making, and how technology can take into account political and social factors that may influence decision-making in

emergency response.

Panel 1

The questions focused on the use of virtual emergency operations centres (VEOCs) and the use of models for contingency planning. Panellists emphasized the need to practice using VEOCs by exercising to improve the skills and engagement of responders. Also important was the need for emergency responders to be comfortable with the software and business tools being used in the virtual environment. Engagement of stakeholders can be problematic when using a VEOC, and adjustments to permissions and virtual meeting procedures are needed to overcome barriers to engagement. However, VEOCs have better “reach” in terms of the numbers of stakeholders that can be engaged.

Models can be used in peacetime as a support for decision-making in peacetime. However, during the COVID pandemic, stakeholders became used to seeing the results of real-time modelling during a response. Panellists recognized that models can and should be used responsibly to support decision-making and different approaches need to be used. A range of modelling tools are therefore required from simple models to adaptations to existing models. Challenges for real-time modelling include access to data.

Panel 2

The questions focused on use of models to assist contingency planning and decision-making. Input from epidemiologists is just one input into the decision-making process. It is important that models expand to take into account other aspects of disease outbreaks including economic, social, environmental, animal welfare and political. Multidisciplinary approaches are needed to model these aspects to assist contingency planning and decision–making.

There are existing communities of practice to exchange best practices, models and so on. There are also examples of countries working together to share results of modelling to contribute to contingency planning; they use their own models but compare results to contribute to and validate conclusions about contingency planning questions.

Different types of models are used to answer different questions. No one model will do everything; a range of models are needed to answer complex questions.

Decision-makers can use models to help validate their contingency plans, or to determine if they need to be revised.

SESSION II: DIGITAL LEARNING

Chair: Katharina Staerk; **Moderator**: Sylvia Baluka; **Co-moderator**: Bouda Vosough Ahmadi

Background

The following issues were identified while preparing the technical session II:

- What are the digital skills needed to facilitate an effective and prompt response to animal health emergencies? What is the situation now and how could it look in the future?
- How can social learning improve veterinary capacity development?
- Is access to digital tools creating barriers across veterinary roles? Can we support those who do not have access to digital resources? How do we ensure that digitalization of learning does not increase the gap between learners from different settings?
- Are veterinarians equipped with the right digital tools that can enhance their work? Are animal health workers provided with the right digital skills to meet continuous professional development (CPD) and to meet the evidence of capacity development needed by countries?

Objectives

- Discuss how equipping veterinarians with digital skills, enhancing the learning via digital and remote peer-to-peer modalities, and increasing the access to digital learning tools represent an opportunity to develop capacity in the animal health sector for FAST disease control.

Summary

The Chair, Katharina Staerk, opened the session, which was moderated by Sylvia Baluka. The session comprised two presentations delivered by keynote speakers, seven short presentations and two round table discussions. The first part of the session grouped three talks by Christine Thuranira-McKeever (Royal Veterinary College, United Kingdom), Despotina Iatridou (Federation of Veterinarians of Europe), and Corrie Croton (Department of Agriculture, Fisheries and Forestry, Australia). The speakers explored perspectives and challenges of digital innovation in veterinary education and continuous professional development for the veterinary workforce. Corrie Croton presented and discussed a case study concerning the use of virtual reality technology to train animal health workers conducting surveillance for FMD. The second part of the session was opened with a talk by Kevin Bardosh (University of Washington, USA) exploring trust and social learning in the veterinary sector from the perspective of social sciences, followed by a series of interventions by Shehu Shamsudeen (EuFMD), Leah Seabrook (EuFMD), Barbara Alessandrini (World Organization for Animal Health), Cristina Petracchi (FAO), and Katherine Bidstrup (Think Digital Studios, Animal Health Australia, Department of Primary Industries and Regions South Australia, Australia) providing additional insights into different aspects of digital animal health training.

Panel 1

Katherina Staerk opened the first panel discussion by asking what the contribution of online learning could be to formal qualifications and degrees. Despotina Iatridou explained that it can help to ensure the quality of the training in terms of minimum learning outcomes and bring transparency to the training market. Dr James Wood asked what modalities should be used to assess online training and especially practical skills, while Fabrizio Rosso asked whether there is any assessment of the effectiveness of digital learning versus face-to-face training. Christine Thuranira-McKeever confirmed that assessment in online education remains difficult. This might be in part due to the fact that trainers are still trying to teach and assess in the same way as they did face-to-face, while online training requires different approaches. Modalities for teaching practical skills online have not yet been developed, but new approaches will be developed in the future as training providers accumulate more pedagogical experience. New approaches will certainly be developed. Noelia Yusta underlined the difference between building confidence and developing competence and expressed the idea that online learning and virtual reality can play an important role in building trainees' confidence in dealing with real-world situations that they might encounter at a later stage of their training (e.g. exploring an abattoir using virtual reality before visiting

the premises in person). Cornelis Van Maanen asked to what extent virtual reality can replace real experience, as certain universities struggle in ensuring their students a sufficient level of contact with patients. Corrie Croton reflected on the fact that training institutions are already providing web-based training in parallel with face-to-face training: rather than trying to replace face-to-face activities, virtual reality should be therefore used to improve and complete web-based training by making it more active and engaging. Rita Papoula-Pereira reported that one of the challenges encountered by universities during the COVID-19 pandemic was proving that home-based students were producing by themselves the work assigned without external aids. This made it necessary to redesign the assessments in order to ask students not to report factual materials but rather to apply the concepts studied and discuss them critically. In response to a question from the online audience, Christine Thuranira-McKeever reflected on the fact that it might be difficult to integrate microcredentials in veterinary degree courses, but a system could be envisioned at postgraduate level in which practitioners could access little bits of training and build on those in order to achieve higher levels of competence or awards like a postgraduate diploma. Despoina Iatridou explained that the Federation of Veterinarians of Europe promotes digital education as an additional tool to help veterinarians to improve their skills and provide better services.

Sylvia Baluka closed the panel by mentioning the EuFMD Veterinary Paraprofessional Programme. Providing face-to-face training to all those who applied to the programme would not have been possible: the online platform currently in use allowed the programme to overcome this issue and enabled it to increase the number of trainees of the project. Virtual learning can also improve the mutual exchange of knowledge between academics located in different parts of the world, especially when physical travel is not possible due to budget constraints or security issues.

Panel 2

Katherina Staerk addressed the first question to Katherine Bidstrup, asking for more information about the efforts required to develop an augmented reality tool and further details about its intellectual property. The tool was built in approximately six months, as it was based on already existing technology, but the collection of a sufficient number of images of lesions was challenging. The tool is freely available, and the project was funded by the State Government of South Australia and Animal Health Australia, which is funded by the Federal Government of Australia, and thus the intellectual property lies with them.

Beate Conrady asked if and how universities can become part of the FAO eLearning academy: Cristina Petracchi explained that it is possible to contact her in order to discuss what university learning programmes might benefit from the FAO training resources and the best way to integrate them into the university courses. Recognizing university credits for the materials would be then the responsibility of the university. Katherina Staerk provided closing remarks highlighting the fact that technology appears not to be the limiting factor for the process of digital transformation of training, but rather changing our learning habits is the main challenge. Furthermore, accreditation schemes need to evolve in parallel with the new technologies that are being used. She stressed the importance of always considering inclusiveness when designing digital training. Katherina Staerk expressed interest in the idea of combining formal and informal training using “digital batches”, namely the possibility of developing small modules that might be accumulated by trainees to achieve specific training objectives, and she added that it might be interesting to explore whether social learning (learning from and with each other) would be possible online or if instead it would require a blended learning approach. Finally, she acknowledged the work done by FAO and WOAH to innovate animal health learning and underlined that it will be important for these institutions to collaborate with universities, as universities are specialized in education. It will be important to avoid duplications and redundancies and to work in partnership to improve future learning.

SESSION III: VIROLOGY AND DIAGNOSTICS

Chair: Stephan Zientara; **Moderator**: Cornelis Van Maanen; **Co-moderator**: Sylvia Baluka

Background

FMD is a persistent challenge for the livestock industry in many countries. The identification of virus-host interactions is critical for understanding the host defence against this virus infection and can provide insights for designing effective vaccines or drugs to prevent and control the spread of FMD. This session was elaborated with the following observations and questions:

(i) There has been tremendous progress in molecular epidemiology of viral diseases, particularly fuelled by the COVID-19 pandemic global response, and one can wonder how diagnosis and control of FAST diseases can benefit from recent innovations in molecular diagnostic methods and platforms such as next generation sequencing (NGS).

(ii) In addition, diagnosis of FAST diseases is still often negatively impacted by the challenges of sample collection and sample transport to national reference laboratories from remote areas and under adverse conditions. The session may explore how innovations in field-based diagnostics such as lateral flow immunoassays and biosensors may contribute to improved diagnosis of FAST diseases.

(iii) Finally, the session aims to address how digital technology through automated tools and dashboards can contribute to more timely diagnosis, molecular analysis and information sharing of FAST diseases.

Objectives

- Consider how modern technologies and digital transformation can support and improve the diagnostic capacity for FAST diseases and ensure availability of diagnostics, personnel and capacities where they are most needed.
- Discuss how understanding the host defence can provide insights for designing effective vaccines or drugs to prevent and control the spread of FMD.

Summary

The Chair, Stephan Zientara, opened the morning session, which was moderated by Cornelis Van Maanen and Sylvia Baluka. The session comprised two presentations delivered by keynote speakers, six short presentations, and two round table discussions.

In their keynote presentations, Donald King (The Pirbright Institute, United Kingdom) gave a snapshot overview of some of the novel viral diagnostic technologies, and more specifically of the innovations in molecular diagnosis, next generation sequencing and molecular epidemiology for FAST diseases. He started by reminding the participants that a presentation on novel technologies was given back in 2008 and encouraged the livestock sector to reflect on what is to be achieved with these technologies, what the demand is for these new technologies and how the technologies developed at the laboratory can be translated in field techniques for routine use. Haixue Zheng (Lanzhou Veterinary Research Institute, Chinese Academy of Agricultural Sciences, China) discussed virus-host interactions in FMD virus infections and further reflected on the feasibility of using antiviral medicine in FMDV control and prevention in terms of pharmacokinetics, efficacy and safety both for targeted animals and food consumption, and compounds that could be registered and made available as soon as possible.

Sabine Delannoy (ANSES) presented IDENTYPATH, the genomic platform of ANSES for molecular detection and typing of pathogens, while Andrew Shaw (The Pirbright Institute, United Kingdom) introduced the complete genome sequencing of FMDV using nanopore sequencing. Morgan Sarry

(ANSES) discussed the contribution to viral persistence of the interplay between FMDV 3D polymerase and the type I interferon response, and Haoran Li (Wageningen Bioveterinary Research and Lanzhou Veterinary Research Institute, Chinese Academy of Agricultural Sciences, China) described epitope mapping of FMDV 146S specific single-domain antibodies by cross-linking mass spectrometry. Finally, Efrem Alessandro Foglia (Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia Romagna, Italy) presented a preliminary validation of multiplex Eurasia lateral flow device for on-field identification and serotyping of FMDV serotype O, A and ASIA1, and Michael Eschbaumer (Friedrich-Loeffler-Institut, Germany) closed the session with the presentation of an experiment showing that full-length genomic RNA of FMDV is infectious for cattle by injection.

Panel 1

Panel 1 was comprised of Labib Bakkali Kassimi (ANSES), Santina Grazioli (IZSLER) and Donald King (The Pirbright Institute, United Kingdom).

It started by reflecting on the application of antiviral agents in FMD-free countries, acknowledging that stamping out and vaccination still remain the main principles for FMD control. Discussions highlighted that *in vivo* safety of these antiviral agents in different species and activity in animal products are not documented enough. It was also highlighted that the risk of escape variants that would not be sensitive to these molecules, but also that the stability of these agents, are not yet demonstrated. In addition, building the dossier to get market release permission for one antiviral agent to be used in the field is a long process. Therefore, producing a stable and affordable antiviral remains a challenge. The panel members further highlighted the inherent challenges related to the antigenic variability of FMDV on the activity of antiviral agents. They also highlighted that the new technologies presented still rely on detection of the first clinical case, and they discussed the interest to invest more in environmental sampling that would assist the population-level early detection of FMDV circulation associated with asymptomatic clinical expression, including environmental sampling, wastewater sampling, and bulk milk sampling that may be used in the United States of America in case of FMD outbreaks in the dairy sector.

Costs to set up and run new diagnostic technologies may still be prohibitive in many countries. What is needed are first line tests that are cheap, easy to perform and will provide quick results to implement immediate control actions. As a first line test LFDs seem to be useful tools as shown during the COVID-19 pandemic, rather than PCRs that need expertise, reagents, instruments and dedicated facilities. Conventional PCR might suffice in endemic countries rather than real-time PCR, but what would be needed is a single generic PCR reagent and a set of disease specific primers ready to use (not a disease kit approach). This would ensure sustainability and familiarity. Also, it should be recognized that for many countries, FMD is not the priority disease. Therefore, more efforts should be made towards a multidisease surveillance approach.

Overall, the importance of training for disease recognition, reporting and sampling is key. Time to confirmation may be lost because disease awareness in free countries fades and sampling is delayed. However, it was stressed that molecular epidemiology is still very important to plan long-term control of FMD where resources allocated to control are scarce. This may require a lot of sequence data, and hopefully, price of sequencing will come down.

Panel 2

Panel 2 elaborated on the recommendations of the special committee on biorisk management for inactivated LFD-FMD handling at laboratories, including non-reference laboratories. Further, *in vitro* inactivation experiments of viruses (incl. FMDV) on biosample collection cards were discussed; these cards may be appropriate vessels for inactivated virus transportation, with the advantage of being cheaper than LFDs.

SESSION IV: VACCINOLOGY

Chair: Prof. James Wood; **Moderator**: Martin Ilott; **Co-moderator**: Bouda Vosough Ahmadi

Background

Innovative vaccine technological platforms offer many advantages over conventional vaccines, but to date the technology has not resulted in authorization of many commercial vaccines against FAST vaccines. The development of novel FAST vaccines could improve the safety and efficacy profile and also improve their availability given that their manufacture does not require high containment facilities. There is a need to better understand any barriers to the application of such technologies to veterinary diseases, especially in light of the success of the rapid roll out of COVID-19 vaccines in the human sector using novel technology platforms.

Access to evolving strains and genetic sequences is critical in developing new vaccines to match evolving field strains. The Nagoya Protocol is designed to achieve fair and equitable sharing of benefits arising out of the utilization of genetic resources, thereby contributing to the conservation and sustainable use of biodiversity, but this has led to changes in the way that pathogens and sequences are accessed that have delayed the development of new effective vaccines.

The veterinary sector is undergoing a digital transformation characterized by the integration of new technologies into every aspect of disease surveillance and control. The current coronavirus pandemic has accelerated this trend with animal health professionals having to overcome many challenges by using new technologies. How is the application of such technology improving the monitoring of animal health disease management and the optimal use of vaccines?

The principles of the 3Rs (Replacement, Reduction and Refinement) were developed over 50 years ago providing a framework for performing more humane animal research. FMD vaccine development and testing requires a severe challenge to demonstrating immunogenicity/potency according to international standards, and routine batch release potency assays may use a significant number of animals. Advances in *in vitro* test development, improvements in manufacture and application of new technologies offer the opportunity to integrate the 3Rs better into FMD vaccine testing and quality controls.

Objectives

- Examine developments in innovative vaccine technology platforms and identify those that could be most promising in the development of new vaccines for FAST diseases that ensure safety and provide vaccines that are at least as efficacious as conventional products and can be manufactured, transported and administered as cost-effectively as possible to make them affordable for widespread use.
- Better understand the challenges and barriers of introducing new vaccine strains for FAST diseases and identifying a framework that minimizes the administrative steps and ensures the rapid sharing of new strains of pathogens with vaccine manufacturers that does not inhibit the investment in new vaccines.
- Explore the key issues that impact FAST vaccine availability and how we capture the best practice from innovative projects to ensure the supply of high-quality FAST vaccines with the relevant strains for the regions where they are used.
- Identify new technologies that can improve the deployment of FAST vaccines in the field to minimize their wastage during vaccination campaigns.
- Investigate how to apply new technologies and tests to improve the application of the principles of the 3Rs to FAST vaccine development and production.

Summary
The Chair, Professor James Wood, opened the afternoon session, which was moderated by Martin Ilott. The session comprised three presentations delivered by keynote speakers, five short presentations and a round table.

The first part of the session was formed by two keynote presentations from Bryan Charleston (The Pirbright Institute, United Kingdom) and Erwin van den Born (MSD Animal Health, Netherlands) on novel vaccine technology platforms. The application of RNA and vector vaccines to combat the COVID-19 pandemic has shown that these and other new vaccine technologies have great potential to combat human and animal diseases. The speakers examined the advantages and some of the challenges for novel technology platforms and some of the regulatory issues required to ensure the safety to target animals as well as consumers of products of vaccinated animal origin and the environment. New vaccine technologies must be transferable to large scale manufacturing and the cost of vaccines affordable for stakeholders. It was also emphasized that traditional technology still has a role, combined with structural vaccinology for better understanding of antigenic structures and their role in influencing immune responses with the aim of improving vaccine efficacy. Pascal Hudelet, the third keynote speaker, focused on the barriers to access pathogens that fall under the Nagoya Protocol, implemented in 2014 to ensure fair and equitable sharing of the benefits arising from the utilization of genetic resources but which is creating challenges for manufacturers seeking to develop new vaccine strains from new field isolates or their sequences.

The second part of the session covered a range of topics on FAST vaccine availability through a new system for prequalification and introduction of an FMD vaccine challenge project in East Africa, development of innovative *in vitro* potency tests for FMD vaccines and assessment of humoral responses, and the use of digital technology to better monitor animal disease management and effective vaccination campaigns. Aldo Dekker (WBVR-Lelystad, Netherlands) opened the session with a presentation on the options for replacement of FMD vaccine potency tests with a focus on the application of *in vitro* tests to reduce the variability of such tests and apply the principles of 3Rs to FMD vaccine production. Karelle De Luca (Boehringer Ingelheim Animal Health, France) presented the results of her team's research into the glycosylation of the Fc fragment of immunoglobulins and their influence on the immune responses to FMD in pigs. Claire Richaud (MSD Animal Health, Netherlands) provided an overview of the use of smart farming technologies that provide efficient and rapid monitoring of the health and welfare of farms animals and can support the detection and management of disease outbreaks. David Mackay (EuFMD) presented on vaccine security and how a prequalification system for FAST vaccines can support the availability of high-quality vaccines linked to long-term supply arrangements. Jeff Hammond (FMD Industry Expert, GALVmed) provided a summary of the "The AgResults Foot and Mouth Disease (FMD) Vaccine Challenge Project", an eight-year, USD 17.68 million prize competition that supports the development and uptake of high-quality quadrivalent FMD vaccines tailored to meet the needs of Eastern Africa.

Panel 1
Martin Ilott opened the session by asking the panel: "How we can translate the rapid development, testing, large scale manufacture and regulatory approval of COVID-19 vaccines in the human sector to veterinary vaccines? What do you consider needs to be put in place in the veterinary sector to build on the momentum gained from the experience with COVID-19 vaccines?" Erwin van den Born explained that to do this in animal health we would need a compelling reason to change the current structures and systems that govern the development and regulation of veterinary vaccines. However, he said that regulatory frameworks have changed to allow platform technologies and was confident that RNA platforms and other novel technologies would be approved for the veterinary sector. Bryan Charleston stated that we were fortunate that COVID-19 was a coronavirus, and so the vaccine development for humans could build on a lot of previous research in the animal health sector; we knew what the protective antigens were. This was also a good example of why we cannot stop the underlying basic scientific research into immune responses and structural vaccinology that provided the scientific

understanding to develop an effective human COVID-19 vaccine.

David Mackay stated that progress had been made with the new European legislation on veterinary medicines. Technology platforms fell within the legislation, and therefore once the quality and safety of a novel vaccine platform had been demonstrated, the only requirement for new products to be authorized should be to provide data for target species efficacy. Also, as the introduction of a COVID-19 vaccine was so critical in the face of the pandemic, a higher risk tolerance and lower level of efficacy was accepted, which was considered unlikely to occur in most animal health scenarios. Martin Ilott also noted that, for food-producing animals, the safety to consumers of meat and dairy products from vaccinated animals should be demonstrated, with the example of DNA vaccines where concerns for the potential integration into the genome of vaccinated animals held up the first vaccine authorization in Europe. There were a number of questions about regulatory pathways; the ambition of having many technology platforms approved did not necessarily address the availability of new vaccines, with the example of the equine influenza platform for introducing new strains into existing products that had not been taken up widely by industry. Donald King emphasized that only a few technologies show potential and that it was important to try and identify viable technologies as early as possible for commercialization and ensure a fair sharing of the benefits. Bryan Charleston added that Gates-funded development has a global access clause in grants that means technology must be available to the people that need it. The timeframe for regulatory approval was also discussed with David Mackay noting that this depends on many factors including the quality of the original dossier. Parallel reviews happened during the coronavirus pandemic, and these can help manufacturers manage responses in a more time-efficient manner. Communication helps accelerate the process, for example, when regulators provide training for manufacturers or at pre-submission meetings when the nature of the applications and potential issues can be discussed in advance of the formal application. Pascal Hudelet noted that the process can be accelerated if the application is prioritized, using the example of Bluetongue vaccines in Europe, and alignment of international and national requirements can also facilitate the regulatory process.

Panel 2

Aldo Dekker highlighted that challenge of vaccinated animals for evaluation of the efficacy and potency of FMD vaccines will always be essential when new strains are implemented in vaccine production. However, mindful of the principles of the 3Rs, producers are using alternative *in vivo* and *in vitro* tests for batch release of vaccine. Producers may either check the antibody response in standardized tests after vaccination or rely on GMP production and the quantification of 146S antigen in the vaccine. Bryan Charleston questioned the continued application of the PD50 challenge standard, considered the “gold standard” of monitoring efficacy and potency given the variability of the test, and suggested that perhaps an alternative system for assessing FMD vaccines should be developed, especially in the interests of the 3Rs. The difficulty in moving away from a standard that had been in use for many decades was recognized, but it was considered that going forward a more sustainable framework was needed given the cost of running such studies in high containment facilities for which there was limited access globally. Donald King asked whether it was possible to define a serological cut-off for protection with heterologous challenges. This was considered difficult to manage across different laboratories and potency tests, and a need to bring together data and a single unified model to select cut-offs and understand differences between viruses that frustrate this objective was recognized.

Karelle De Luca clarified that the results of the studies in pigs were applicable to other species as the glycosylation pathways of the FC portion of immunoglobulins were similar. She emphasized the need for challenge studies to be conducted to better understand the glycoslylation profile that enhances protection. The basic research can support the development of new vaccines with the observation that some adjuvants will modify the glycosylation patterns associated with antibody-dependent-cell mediated toxicity functions. Claire Richaud was asked about potential data protection and privacy issues surrounding access to data collected through the AgTech Technologies system for monitoring animal health and movements. She stated that the data will always belong to the farmer. Farmers are

collaborative in general as long as governments are transparent with how data will be used. A more important question from her perspective is: Are governments ready to harvest and utilize these data?

Jeff Hammond was asked what the key take-home messages were from the AgResults project. The AgResults FMD vaccine challenge project had three objectives: to develop and register high quality vaccines, increase vaccine production and regional purchases, and develop a private sector model through a cost-sharing mechanism. FMDV in East Africa is complex, with five FMD serotypes and at least 15 circulating strains. The World Reference Laboratory for FMD (WRL-FMD) had developed a panel of these strains, demonstrating regional relevance using a viral neutralization test. Jeff Hammond indicated it was important to have a set of defined criteria for vaccine manufacturers to use and to subsidize the production of the vaccine, at least at the start, to incentivize the private sector.

David Mackay explained the rationale for the prequalification system. Many FMD vaccines do no not have full authorizations where they will be used, as demand is limited and unpredictable. Benefits of the system include publicly available independent and verifiable information to inform procurement procedures and an increase in the use of high-quality vaccines that meet international standards. The scheme will be extended in a second stage to include independent testing that should foster the exchange of vaccines, sera and other materials to allow for independent quality control and compliance with WOAH standards.

SESSION V: RISK ASSESSMENT AND MODELLING

Chair: German Caceres Garrido; **Moderator**: Melissa McLaws; **Co-moderator**: Sylvia Baluka

Background

- What innovative approaches and data-driven technologies can advance disease modelling, risk assessment and forecasting?
- How can risk information be shared in a timely, efficient and effective manner?
- How can different data sources be integrated into useful information to assist decision-making processes to prevent and control FAST diseases?
- How can models be used to inform policy and decision-makers for FAST disease prevention and control? What are the best practices for using modelling to inform policy and decision-makers?
- What are the limitations and challenges of using data to model and assess risk? How can we overcome these challenges? How can we deal with uncertainty?
- How can we explain the outcomes of risk assessments and models to the general public if needed?
- How can risk analysis and modelling tools be made available to developing countries? How can we make research results understandable, useful and available to veterinary services and other stakeholders that could benefit from them?

Objectives

Showcase advances and innovations in risk analysis and modelling as suitable tools for using data and transforming it into meaningful information to assist decision-makers to manage the risk of FMD and similar diseases.

Summary

The Chair, German Cáceres Garrido, opened the morning session, which was moderated by Melissa McLaws. The session comprised three presentations delivered by keynote speakers, four short presentations and two round table discussions. In their keynote presentations, Thibaud Porphyre (National Veterinary School of Lyon, France) and Amy Delgado (U.S. Department of Agriculture, United States of America) discussed challenges and solutions for data collection to support modelling and communication of model outputs to policymakers. They provided recent examples of the successful use of modelling results to inform policy and key issues that need to be addressed by field epidemiologists and modellers to develop trusted, sustainable modelling partnerships and applications. Bouda Vosough Ahmadi (EuFMD) presented the Vaccine Demand Estimation Model for FMD (VADEMOS), a tool for the estimation of FMD vaccine demand, while Roberto Condoleo (EuFMD) presented the Risk Monitoring Tool for FAST diseases (RMT-FAST), a semi-quantitative framework to monitor the risk of disease introduction into EuFMD MNs. Both these tools developed by the EuFMD represent examples of how modelling can inform the decisions of policymakers and support them in defining the best strategies for emergency preparedness and allocation of resources. Margarida Arede (Facultat de Veterinària, Universitat Autònoma de Barcelona, Spain) and Alexis Delabouglise (French Agricultural Research Centre for International Development, CIRAD, France) described modelling studies conducted at national or regional level and discussed how their results might support decision makers and inform risk-based strategies for FAST diseases. Finally, Mike Tildesley (University of Warwick, United Kingdom) gave a closing keynote presentation that reflected on the use of models to inform decision making in real-time during an outbreak based on experiences from COVID-19 and FMD outbreaks.

Panel 1

Melissa McLaws opened the first panel discussion by asking Amy Delgado to discuss the main elements that decision-makers should consider when designing policies and what she would suggest to increase opportunities for modellers and analysts so that they can be an influential part of the policymaking process. Amy Delgado explained that, although policymaking is unique in each country, when planning their emergency response most countries work in a cycle, first selecting the diseases of main interest and

then running exercises and simulations to improve preparedness. Simulation exercises often highlight existing doubts and uncertainties about the best strategies to be adopted in the case of an emergency. It is at this point that modellers and analysts can play an important role by providing insights into the potential outcomes of different strategies in terms of health and economic impact. Once the outbreak hits, additional unforeseen policy questions arise, thus initiating a rapid turnaround of evaluating options and providing advice with modelling and analysis. Thibaud Porphyre added that during the early stages of an outbreak most of the actions are based on contingency plans previously developed: modellers therefore play the role of data analysts to provide a better understanding of the current situation. The need for more advanced modelling usually comes at a later stage when policymakers start to think about consequences of the different control strategies. German Cáceres Garrido emphasized the importance of building a close relationship between research and policy so that policymakers can get a clear understanding of the usefulness and limitations of model outputs. Bouda Vosough Ahmadi and Thibaud Porphyre added that this process creates trust and should start in peace time, so that all stakeholders can understand the questions without misunderstandings and are given the chance to know tools, data, shortcomings and limitations.

A question from the audience focused on the differences in the terminology employed by professionals with different backgrounds or working in different sectors or countries. This sometimes generates misunderstandings and hampers the use of shared recording systems by making data less comparable. Would it be better to harmonize the language or to use better translators? Thibaud Porphyre underlined that official translators sometimes do not know the field, and that it is thus better to involve experts directly in the projects. Addressing social, cultural and linguistic differences and deciding which is the standard is challenging and time consuming.

Another intervention from the audience underlined the importance of public debate: making data publicly accessible (for example, using dashboards) can stimulate public discussion about the quality and meaning of data; this kind of discussion occurred during the COVID-19 pandemic. This could broaden the audience of stakeholders without keeping it limited to a small number of experts. Thibaud Porphyre commented that, on the other hand, public debate can generate a level of confusion that might be difficult to manage during an outbreak. Furthermore, when the same public data are presented to the public using different formats and analyses, dashboards and so forth, the public usually focuses on the differences rather than on the overall meaning. This, therefore, requires a massive communicative effort to explain differences, uncertainties and variability. Although public debate is important, it might be difficult to handle it during an emergency. Amy Delgado added that in the United States of America only a very tiny subset of people is involved in agricultural production and familiar with livestock disease and related control measures. Therefore, veterinary services tend to prioritize the relationship with the people who will be impacted by the decisions within the agricultural community. Other countries certainly present different contexts requiring a higher level of public debate. Sylvia Baluka agreed on this point and reminded the participants that, in certain contexts, leaving out some of the actors and not addressing their information gaps might undermine the efforts made to control an emergency.

Starting from the consideration that nowadays several epidemiological models rely on data collected thanks to international platforms, a question from the audience asked for the panellists' opinions on how to ensure the proper collection and analysis of data and the production of unbiased results. Thibaud Porphyre agreed on the importance of considering how datasets coming from different sources are integrated with each other, as they are based on different sources (such as open-access data, business, regulatory bodies and academic research). Checking the quality of datasets is a different but equally important aspect. The volume of data does not imply that the dataset is of high quality. In order to address these challenges, epidemiologists, data managers and data scientists must concentrate on how to make data collection more representative. Furthermore, the information about data collection, recording and extraction should always be disclosed for each dataset so that everyone can assess its validity. Finally, epidemiologists cannot overlook the importance of data cleaning, which still requires a lot of time and effort. In response to input from the audience online, the panel reviewed the privacy and

legal issues related to cloud data storage: several concerns derive from the physical location of data, as political or social instabilities or other legal issues might lead to complete loss of the data.

Panel 2

Melissa McLaws started the discussion by asking Alexis Delabouglise how the results of his research on animal mobility could be applied practically to the policymaking environments in the setting where the research was done. Alexis Delabouglise explained that variables such as biomass, rainfall, and market prices might be monitored on a regular basis by government agencies and provide some signals for predicting the extent and intensity of livestock movements in the subsequent months and for orienting surveillance and control actions. However, since the model was applied to animal movements recorded in Senegal in a single year, the study should be replicated in different study areas and regions and in different years. Mike Tildesley stressed the importance of communicating uncertainty when presenting the outcome of research to policymakers to ensure integrity, correct interpretation of results, and avoid credibility loss by scientists. Margarida Arede added that, when communicating research outcomes, it is important to specify whether they are preliminary results in order to open the way for subsequent updates as new research and higher quality results become available. Roberto Condoleo remarked that the aim of modelling studies is to provide the best possible advice in contexts characterized by lack of data. For this reason, the answers provided cannot be perfect but are the best possible ones based on the knowledge available. Melissa McLaws agreed on the fact that this is the critical point: How do we make decisions in an uncertain environment and how can models help us with that? German Cáceres Garrido added that modelling studies represent one of the multiple sources of information that policy makers should use. In particular, their results should be always combined with the information derived from field observations. In response to a comment by Cornelis Van Maanen, Mike Tildesley reiterated the fact that, at the start of an outbreak, models alone cannot provide the answer but can only be part of the answer: Several experts other than modellers need to be taken into account.

Sylvia. Baluka asked the panellists how modellers can provide feedback to field veterinarians involved in primary data collection in the field in order to allow them to improve the quality of the data collected. Mike Tildesley responded stating that modellers are aware that there is always a limited capacity to collect data, and it is therefore important to think about strategies to target data, as some datasets might be really crucial when trying to fit a model to an outbreak, while others might be less important. R. Condoleo added that sometimes colleagues operating in the field do not have a clear understanding of the importance of primary collection and of what the data are used for. It is therefore essential to increase their involvement and awareness in this regard. Melissa McLaws agreed and added that data collected during the 2001 FMD epidemic in the United Kingdom are still being employed and discussed today.

Cornelis Van Maanen asked whether it might be worth considering involving social scientists or communication experts to ensure proper communication of technical concepts to policymakers and to a wider audience. Mike Tildesley agreed on that: modellers are all aware of the importance of communicating uncertainty but finding the best way to do that is challenging. On the other hand, he acknowledged that the general public is actually more familiar with the concept of uncertainty than scientists may think (for example, the concept of uncertainty is always associated with weather forecasts).

In response to a question from the audience online, Melissa McLaws and Mike Tildesley reflected on the fact that different outbreaks, although similar, always differ to some extent. Thus, when a new outbreak takes place, lessons learnt from previous ones can be considered, but it also important to consider the particular characteristics of the new one.

SESSION VI: SURVEILLANCE AND CONTROL

Chair: Giancarlo Ferrari; **Moderator**: Carsten Pötzsch; **Co-moderators**: Bouda Vosough Ahmadi, Sylvia Baluka

Background

The following issues were identified while structuring Session VI:

- How are information and communication technologies improving data collection and reporting and guiding informed and timely decisions?
- What innovative approaches can balance costs and benefits of disease surveillance and control actions for low- and middle-income countries?
- How can experience and research from COVID-19 surveillance, control and socioeconomics benefit FMD/animal health surveillance and control?
- What are novel approaches in evaluating surveillance systems and overall surveillance system sensitivity?
- What are new FMD control approaches to ensure continuation of business in endemic countries?
- How can simultaneous surveillance and control approaches for different FAST diseases increase resource efficiency in countries?
- What is the future of molecular techniques like whole-genome sequencing and metagenomics in FMD/animal health surveillance?
- How can in-field technologies and Artificial Intelligence be used for improving surveillance and data collection?
- How do socioeconomic approaches and public-private partnerships contribute to improved FAST surveillance and control?

Objectives

- Gather ideas and innovative approaches for future field application of research outputs and outcomes, and facilitate discussion and contacts between science, policy and applied FAST surveillance and control.
- Share innovative experiences, ideas and approaches for the development, implementation and monitoring and evaluation of FAST surveillance and control programmes.

Summary

The Chair, Giancarlo Ferrari, opened the afternoon session, which was moderated by Carsten Pötzsch and Bouda Vosough Ahmadi. Giancarlo Ferrari framed the content of the session, acknowledging that the session was addressing two separate but interrelated activities: surveillance activities and control activities. Obviously, disease surveillance allows targeting best control options, but surveillance objectives are heavily dependent on the context in which surveillance is implemented, for example, towards early detection in disease-free settings or towards better understanding of disease dynamics in endemic settings. The keynote presentations were given by Keith Sumption (FAO Chief Veterinary Officer) on lessons learnt on SARS-CoV-2 and implications for FAST surveillance and risk reduction and by Angus Cameron (Ausvet Europe) on sustainable market-driven early disease detection approaches. Two additional presentations were provided by Simon Gubbins (The Pirbright Institute, United Kingdom) on longitudinal animal and environmental sampling for FMDV in Northern Nigeria and by Vasili Basiladze (CVO, Georgia) on the Progressive control pathway for FMD progress in Georgia and how it advances FAST control completed the topics for the first panel discussion.

<u>Panel 1</u>

Carsten Pötzsch opened the discussion with the question of whether Global FMD Control Strategy needs to be brought closer to the One Health paradigm, taking into account the presented similarities between FMD and the SARS-CoV-2 pandemic and the way these are controlled. Panel 1 reflected on the interests and needs to create strategies for pandemic preventions. It was acknowledged that animal health

services need to ensure sustainable and healthy animal production systems, and include the FMD focus, to ensure the functioning of the other One Health elements. The gains made from more investment in pandemic prevention were discussed, including regarding animal health surveillance, and it was noted that they will lead to a wider system transformation.

The question on reviewing or softening the FMD-free status approach was opened, in view of the challenges associated with the implementation of the *zero COVID-19* policy. Panel 1 elaborated on what an acceptable level of control for FMD could be and on what level of FMD burden could be acceptable, this concept being at the backbone of the PCP-FMD. It was acknowledged that it might be challenging for countries to answer such questions while developing control strategies, but such questions steer the importance of understanding the views and expectations of the livestock producers. In particular, discussions addressed the adequacy of economic incentives for intensive producers to achieve eradication and access the international market with export opportunities. It was envisaged that while providing intensive producers relevant incentives, these incentives may allow them to support eradication or further control in other segments of the livestock sector where FMD control may not or cannot be a priority. It should be kept in mind that for some countries, export is not a concern; for some other regions, the export market is not FMD sensitive. It was concluded that there should be market forces to influence the level and intensity of FMD control, as this should not be solely the responsibility of the government. Such a co-benefits approach would allow the sustainable transformation of livestock systems. Finally, the issues of incentives for reporting were addressed, and it was pointed out that there is often social and community stigma for farmers when reporting FMD suspicion, partly due to the draconian government responses following these reports. Technologies like environmental sampling may represent an alternative population-level surveillance tool, reducing stigma issues and allowing sufficiently robust surveillance in endemic settings.

Panel 2

The second panel discussion was moderated by Carsten Pötzsch and Sylvia Baluka and followed the presentations by Sarah Mielke (U.S. Department of Agriculture, Animal and Plant Health Inspection Service, United States of America) on what data can demonstrate about FMDV serotype C extinction; Rosemary McManus (University of Glasgow, United Kingdom) on investigating gaps for novel animal health surveillance data within Scotland; Michel Bellaiche (Kimron Veterinary Institute, Israel) on the potential use of drones in surveillance of FAST diseases; Antonello Di Nardo (The Pirbright Institute, United Kingdom) on OpenFMD, a data sharing and analytical portal to enhance genomic and epidemiological surveillance of FMD; Bolortuya Purevsuren (WOAH) on digitalization of FMD datasets using the visualization tool on SEACFMD portal; and Polly Compston (Royal Veterinary College, London, United Kingdom) on identifying and addressing the barriers to effective FMD vaccination in Nakuru County, Kenya. The topics addressed during the conversation with panellists covered data-policy issues (surveillance data, data collected from drones), and farmer acceptability of sensor-driven surveillance, available automated processing tools that translate images into putative differential diagnosis.

WORKSHOP - FAST RISK MONITORING

Moderators: Melissa McLaws, Carsten Pötzsch, Roberto Condoleo, Etienne Chevanne

Background

Countries are at constant risk of the introduction of FAST diseases and invest in preventive measures such as border controls to reduce this risk. Pathogens can cross borders through different pathways, including through the trade or movement of live animals and their products, vectors and fomites, such as vehicles and travellers' footwear. The intensity of these pathways (i.e. connections between countries) as well as the prevalence of disease in the source countries will determine the magnitude of the risk; however, these are not constant over time. Through characterizing and monitoring specific risk determinants, countries can tailor preventive measures to be more targeted and effective.

The goals of the EuFMD workplan include:

- improving preparedness for management of FAST diseases' crises by EuFMD Members and across Europe as a whole; and
- reducing risk from FAST diseases from the European neighbourhood to Members and Europe.

Activities to achieve these goals include gathering and reporting information on FMD occurrence globally and the FAST disease situation in the European neighbourhood (see FAST reports, Quarterly reports and dashboards) as well as the development of the Risk Monitoring Tool for FAST diseases (RMT-FAST).

This workshop is linked with Session 5 (Risk assessment and modelling) and Session 6 (Surveillance and control). It gathered participants with high-level expertise on surveillance, risk assessment and modelling, and risk management, with representation from academia and governments.

Objectives

- Understand current practices and tools to assess and monitor the risk of incursion of FAST diseases.
- Identify gaps in knowledge or tools to assess and monitor the risk of incursion of FAST diseases.

Expected results

- Mapping of the key risk-assessment tools and information sources used by the audience, including strengths and limitations
- Feedback on EuFMD activities to facilitate risk assessment (reports, RMT-FAST).
- Identification of gaps and options for EuFMD to improve activities related to risk monitoring for FAST diseases

Summary

Fabrizio Rosso (EuFMD) and German Caceres Garrido (EuFMD STC) opened the workshop, referring to the EuFMD work programme on *Risk Reduction* to EuFMD MNs. The results are expected to inform the EuFMD work programme and be used to reflect on the development of the next four-year strategy (2023–2027). Although risk information is available, the audience was invited to reflect on methodologies to collect such data, and on tools that can be used to assess change in risk of FAST pathogen incursion into EuFMD MNs.

Current practices to monitor risk

Melissa McLaws moderated the first discussion, which focused on understanding current practices and information sources to monitor the risk of FAST diseases. A PADLET® board collated participants' inputs, summarized in the table below. The key points from the PADLET board and following discussion are:

1. A wide range of information sources are available and used to monitor disease risks. Each of these has different strengths and limitations, according to the perspective of the user. Common considerations regarding information sources included:
    a. whether or not the information is official and verified;
    b. timeliness, completeness and scope (some sources only report on certain geographic areas) of the information; and
    c. ability to compile, extract and download raw data.
2. There are numerous methods, tools and frameworks used to assess risk information. These have been developed to fit different purposes such as unique country perspectives, assessment of particular types of pathogens (e.g. zoonotic or vector borne) and the time and technical skill required for the analysis.
3. Information regarding connectivity is also critical.
    a. UNComtrade gathers official trade of commodities (connectivity data) but does not include data on informal or illegal movement which is unknown by nature; no proxies are known at the moment, and it might be hard to validate the approach. There may be opportunities to use resources that monitor criminal networks as they are in charge of most of the illegal wildlife trade.
    b. Flight data is of interest but may refer to the last airport visited; therefore, the gap of information for travels with multistops should be considered. There is also interest in truck data.
    c. Connectivity data should be made available at European Union level and country level.
4. Disease monitoring takes significant time and resources that should not be underestimated. To follow-up on the reported information requires complex networks of dedicated people and information, which may finally result in a short summary to disease managers.
5. Risk information is fragmented, and usually, reports focus on source event and connectivity but not on the state of surveillance and control of animal disease in a country.
6. Prioritization of diseases and concerns about monitoring are dictated by the scale of response and the scale of interest. Risk prioritization should be very well thought out and is of utmost importance; it should also be regularly reviewed and updated.

RISK INFORMATION TOOLS

Strengths	Gaps/limitations
World Animal Health Information System (WAHIS)	
• Official information from country Delegates • Good for examining large trends and retrieving ready-made reports	• Under-reporting • Timeliness of reports (delays esp. from endemic areas because immediate reporting is not required unless it is an unusual event) • Data that may be modified by countries to ensure confidentiality – What are the impacts of such changes on risk prediction? • Issues to extract data and manipulate WAHIS+ (not user-friendly interface) • Geographical information not easily available, as well as historical data • Not useful to gather raw data (data is often aggregated spatially and geographically)

FAO EMPRES-i	
• Better usability of data compared to WAHIS (easy download, explicit spatial and temporal data) • FAO has a good network that allows acquiring additional information	• The correlation between this database and the WOAH-WAHIS and WRL-FMD should be made clear.
ProMED	
	• Unofficial data • Narrative format (mail) difficult to compile and extract data from. Any application programming interfaces available to extract data more easily?
FMD base	
	• Few comments – not used at the moment
EuFMD/WRL-FMD Joint quarterly report	
	• Tables cannot be extracted as csv. files • Risk-assessment chart (at the end of the report), is only for Europe at the moment
African Union – Interafrican Bureau for Animal Resources (AU-IBAR) epidemiological bulletin	
	• Only for Africa
Google	
	• Variability of reports, resource consuming to screen reports • Does Google search a good representation of the interest of the whole society or of a section of it? Concern on the level of bias of risk information from these data
Platform for Automated extraction of Disease Information from the web (PADI-web)	
Web tool developed by CIRAD, still under development and improvement, in the frame of an EU One Health project called MOOD	
Animal Disease Information System of EU (ADIS)	
Very useful	Access may be limited to official veterinarians
SEACFMD Portal and Toolbox	
FAST report	
UK DEFRA website (Animal and Plant Health Agency Disease Reporting System)	
Plateforme de veille international ESA (here)	
Google scholar	

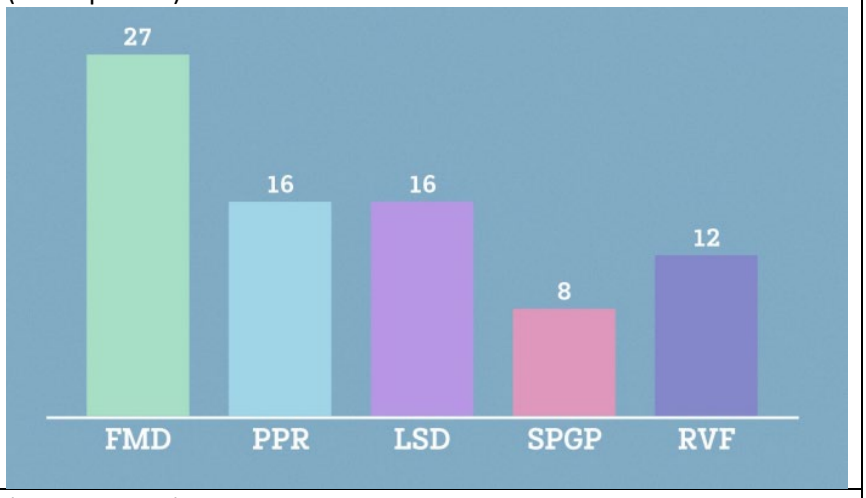
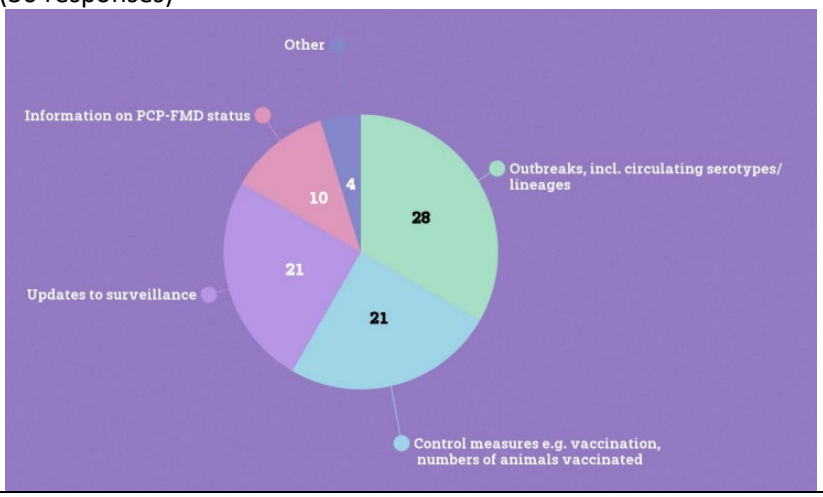
Comments:

- Overall, the **variability of reports** (format, content and source) is one issue to address when it comes to data integration for risk assessment.
- WRL-FMD is planning to integrate FMD data from the WAHIS system on a more user-friendly interface, with more easily accessible database.

RISK ASSESSMENT TOOLS

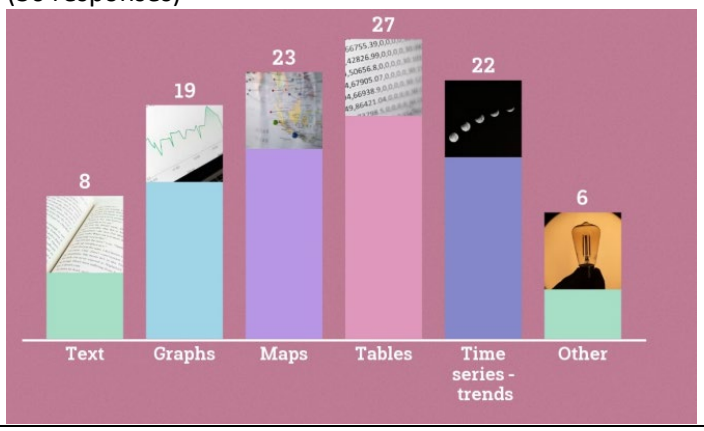
Strengths	Gaps limitations
Rapid risk assessment tool for introduction of exotic disease to the Swedish animal population (SVARRA)	
• Qualitative rapid risk assessment tool at Swedish National Veterinary Institute (Swedish: Statens veterinärmedicinska anstalt, SVA) SVA • Uses a systematic approach • Easy to use	• No automatization
Method for INTegrated RISK assessment of vector-borne diseases (MINTRISK)	
• Semi quantitative • Flexible tool	• Only for vector borne disease • Developed for disease-level questions but not on serotypes/strains (some questions may need to be more specific) • Semi-easy to use as it is sometimes difficult to understand how inputs are related in the model • Poor handling of its sensitivity to uncertainty
Collaborative Management Platform for detection and Analyses of (Re)Emerging and food-borne outbreaks in Europe (COMPARE)	
• Quantitative • Uses public data • Quick to update • Compares 10 diseases	• Requires skills in terms of building and running the model • Needs update of many parameters
Development of SPatial risk-assessment framework for Assessing exotic disease incuRsion through Europe (SPARE)	
• Quantitative • Uses public data • Quick to update	• R based; resource demanding (skills in terms of building and running the model) • Difficulties to include pathways such as trucks, farm workers and hunters
WHO R&D blueprint for epidemics (here)	
Independent group of experts reviews the evidence and generates a revised list of recommended pathogens for accelerated scientific research by the global community. New list will be available by the end of 2022.	
Spill over global: viral risk ranking (here)	
Explores and directly compares hundreds of viruses, host and environmental risk factors to identify viruses with the highest risk of zoonotic spillover from wildlife to humans	
Emerging Zoonoses Information and Priority systems (EZIPS)	
Contact international colleague	
Discontools (here) (Semi-qualitative tool)	
GInaFIT Tool (Quantitative)	
Quantitative Microbial Risk Assessment (QMRA) (Quantitative)	
MicroHibro (Quantitative)	
Technical guidelines on Rapid Risk Assessment(RRA) from FAO (here)	
@Risk Quantitative tool from EpiX analytics	
Rapid Risk Assessment (RRA) tool Quantitative Rapid Risk Assessment from Wageningen University	
European Centre for Disease Prevention and Control (ECDC) Rapid Risk Assessment (RRA) Tool	
D2R2: Disease briefing, decision support, ranking and risk assessment (Quantitative)	
NORA (from Finland)	
International Disease Monitoring tool (IDM) Department for Environment Food & Rural Affairs, UK (DEFRA) Semi-quantitative, for risk of incursion	

C. Pötzsch moderated the second discussion, using the Mentimeter® tool to collate participants' inputs on the EuFMD quarterly FAST report and global FMD report (jointly published with WRL).

Do you use these reports/dashboards, or would you consider using them (now that you know them) in your work?	(31 responses) 30 Yes/1 No
Which FAST disease(s) do/would you use the reports/dashboards to obtain information about?	(30 responses) 
What information in the reports/dashboards do /would you find most useful?	(30 responses) 

Discussion:

- A broad range of users access EuFMD tools, and it is not possible to serve all needs and expectations. The **core stakeholders** (target audience for such reports) could or should be identified.
- Vaccine matching data is very important, but it should be made clear that vaccine data should not be *overestimated*, as the vaccine itself does not dictate the success or failure of a vaccination campaign -> potential to **include information on cold chain, vaccination protocol, and quality of the supply chain.**
- The **political and security situation** in some countries should be taken into account so that the reader can better interpret the information.

How would you like to see data in the reports and dashboards presented?	(30 responses) 

Discussion:

- **Spatial data should be as accurate as possible;** aggregated data at the regional or country level is difficult to use for research.
- Reports and dashboard do **have different audience and communication objectives**. These communication products should therefore be addressed separately.
- Reports should be standardized as much as possible. A difference should be made between descriptive texts versus **interpretative summaries** (e.g. "*This is the first report of XX in XXX*"); the latter may be more useful to end users.
- It would be useful for researchers and modellers if **tables were available for download,** e.g. in csv. format. However, data policy issues need to be addressed, including ownership, and accuracy of raw data available for download.

Do you think that reports (with a defined interval, e.g. quarterly) are necessary, or are interactive dashboards instead of reports more useful/sufficient?	(29 responses) 15 for reports; 5 for dashboards; 18 for dashboards supplemented by brief newsletters *Discussion*: A combination of tables and more dynamic time series might be needed.
What are your suggestions for EuFMD to improve reports/dashboards and their use for risk monitoring?	(17 respondents) *Discussion*: Why are the EuFMD dashboards not developed together with WOAH? Do we need dashboards? *Response*: Data sources and need for actuality are different between WAHIS and EuFMD. Users of EuFMD tools include European Commission, MNs, local decision-makers, risk assessors and risk managers. 

Conclusions

- To better implement changes and improvements, it would be useful to identify the main users of the EUFMD tools.
- While for decision-makers and other users a combination of reports, dashboards and newsletters is useful, for researchers, tables with (raw) data are more appropriate.
- Reports should be in a more standardized format.

RMT-FAST session

Roberto Condoleo provided a short demonstration video, illustrating how RMT-FAST should be used to monitor the risk of entry of FAST diseases and the outputs that are generated. Participants were asked to share comments regarding the tool's parameters and the possible limitations of the tool.

Comments:

- Wildlife pathway of entry should be better defined. Wild animal species present in some countries are *reservoirs* for a certain pathogen meanwhile in other countries there are wild animal species that are known to be important carriers or amplifiers of the pathogen. In some cases, there are no wild animal species in the source country that play an important role in the spread of the pathogen.
- Definition of "live animal contact" can be confusing for the user. It should be clarified that this parameter is about the possibility that domestic animals from the studied source country have the opportunity of getting directly or indirectly in contact with animals of the target country (i.e. trade, common grazing…).
- As risk is not uniform in one country; the possibility of data disaggregation data at sub-national level was asked.
- How should RMT-FAST be validated? It is well known that validation of models concerning the risk of pathogen introduction is very difficult, and most of the generic risk-assessment tools currently available have not been validated yet. Similar difficulties exist for RMT-FAST. However, cross-validation approach, which consists in a structured comparison of the outputs of other similar tools in the context of the same scenario, seems a possible robust methodology to assess the performance of RMT-FAST (see de Vos *et al*., 2020).
- Excel format is easy to "break". It is an issue as you intend to inform decisions with such a tool; it would be advised to change the system while keeping the model if it is seen as fit-for-purpose.
- How should uncertainty in the model be handled (about certain risk pathways)? This is critical especially if you want to compare models.

Recommendation

A follow-up virtual meeting was suggested in the next few months, to go in more detail about critical outcomes.

WORKSHOP - FAST VACCINE AVAILABILITY: IMPROVING VACCINE SECURITY THROUGH LONG-TERM SUPPLY OPTION

Moderators: Martin Ilott, David Mackay, Kathy Gibson, Polly Compton, Jacquelyn Horsington, Bouda Vosough Ahmadi

Background

Vaccine security refers to assuring the availability of a sustainable, suitable supply of an appropriate vaccine as and when the need arises. The capacity to respond rapidly to an incursion of FMDV is of utmost importance to limit the economic, animal health and societal impacts.

The EuFMD has organized several multistakeholder meetings and workshops over recent years to explore the issues surrounding vaccine security, most notably the "Explore options to improve security of vaccine supply against foot-and-mouth and similar transboundary diseases" in Rome in January 2020 and the follow up virtual meeting in January 2022. The principal areas of focus were to utilize a multistakeholder platform (MSP) to develop a system of prequalification of FAST vaccines in advance of need, explore assured emergency supply options and long-term supply agreements to provide better access to vaccines and provide more predictability and develop models that could be used to predict demand (e.g. VADEMOS). A related but separate issue was the impact of the Nagoya Protocol on the development of new vaccine strains. The recommendations and actions from these meetings have been progressed through the activities of the EuFMD, but there remain some fundamental issues for capacity building, supply arrangements and costs that inhibit improved vaccine security.

Identifying suitable business models to ensure the availability of sufficient doses with the appropriate strain(s) within the required timeframe for emergency outbreaks or sustained supply in endemic settings has proved challenging.

Foot-and-mouth disease antigen bank models have been developed and adapted for various scenarios and have proved successful for emergency supply of vaccine within days of mobilization. However, the possibility for developing alternative arrangements for vaccine supply for situations where the vaccine banks have insufficient stocks of the appropriate strain(s) was poorly investigated. An innovative business model such as the assured emergency supply options (AESOP) has been explored before within an MSP, but further exploration of the mechanism for establishing a sustainable business model for AESOP is required. The concept for AESOP was developed in 2018 but yet has not evolved to provide a parallel mechanism to antigen banks to address vaccine availability issues following FMD outbreaks.

Vaccine security presents a particular challenge in the case of FMD vaccines due to several factors including the high costs of production, the need for biocontainment during manufacture, the existence of multiple antigenically distinct serotypes of the virus, and the variable degree of cross-reaction between strains of the same serotype. Added to these is the epizootic nature of the disease and the ultimate goal for control of FMD being to attain the status of "freedom from FMD without vaccination", thereby ultimately eliminating the market for FMD vaccine. For these reasons, FMD vaccine production is a high-risk commercial enterprise, and anything that can be done to provide assurance of the existence, size and sustainability of the market for FMD vaccines will be helpful in promoting vaccine security.

Currently, there are several options that risk managers use to ensure that suitable FMD vaccines are available when needed:

- Managers may attempt to buy vaccines as and when the need arises. However, vaccines of suitable quality and with vaccine strains appropriate for their needs are not always available at the time the need arises. This is particularly the case if a high number of doses is required.
- Managers can put in place strategic reserves of either formulated vaccine or antigens (FMD Antigen Banks). This has the advantage that vaccines are available when needed but can be expensive, particularly for formulated vaccine, and relies on accurate predication of the strains that will be required.

- Managers can come to contractual arrangements with manufacturers to supply defined quantities of vaccines containing agreed antigens within a fixed timeframe from the submission of a request - long-term supply arrangements (LTA) - or assured emergency supply option (AESOP).

The Vaccine Demand Estimation Model for FMD (VADEMOS-FMD) has been developed as a tool to estimate current and future vaccine dose demand for FMD at national, regional and global levels. It aims to bridge the gap between FMD vaccine demand and vaccine production and supply in endemic countries, giving greater predictability to both veterinary authorities for their requirements and manufacturers for production planning and scheduling. The VADEMOS tool is still in its infancy, and there is an opportunity to work with stakeholders to optimize the model to improve vaccine security.

In addition to the availability of high-quality vaccines of the required number of doses there are many other factors that impact the supply and use of FMD vaccines. The socioeconomic factors influencing vaccine take-up are often neglected. There is a need to better understand what additional information, tools or systems are needed in endemic settings for ensuring appropriate vaccine supply for FAST diseases and how these could best be identified and collected.

Objectives

- Understand better what the current barriers to vaccine security are to ensure the availability of sufficient doses of FMD vaccine with the appropriate strain(s) within the required timeframe for emergency outbreaks or sustained supply in endemic settings.
- Explore the key differences between the FMD antigen bank, long-term supply arrangements (LTA) or assured emergency supply option (AESOP) and how they can best be used to improve vaccine security.
- Understand how prequalification can promote vaccine security in general and particularly in the context of LTAs/AESOPs.
- Investigate whether there are other innovative business models that can improve access to suitable FMD vaccine(s) for low- and middle-income countries (LMIC).
- Identify how vaccine demand models such as VADEMOS can be applied to best support MNs and vaccine manufacturers establishing LTAs/AESOPs.

Expected results

- Identifying barriers to vaccine availability and in particular access to key FMD vaccine strains for sustained supply in endemic settings
- Defining the various business models for production and supply of FMD vaccines and antigen banks including long-term options such as LTA and AESOPs
- Identifying the next steps for VADEMOS in how it can better support stakeholders in predicting vaccine demand

Summary

The vaccine availability workshop was a focused physical meeting of invited experts and participants at the OS22. Approximately 30 experts were divided into six groups exploring six separate themes related to vaccine availability:

- Group 1. What are the current key barriers to vaccine security to ensure the availability of sufficient doses of FMD vaccine with the appropriate strain(s) within the required timeframe for emergency outbreaks or sustained supply in endemic settings?
- Group 2. What are the key differences between the FMD vaccine bank models, long-term supply arrangements (LTA) or assured emergency supply options (AESOPs) and how can they best be used to improve vaccine security?
- Group 3. Is there a need to further develop the AESOPs model to improve vaccine availability and are there other innovative business models that can improve access to suitable FMD vaccine(s) for LMICs?

- Group 4. How can the vaccine demand models for FMD and VADEMOS be utilized optimally to improve vaccine security by establishing LTAs or AESOPs that ensure adequate doses of quality vaccines for veterinary authorities and encourage investment in capacity by manufacturers?
- Group 5. How can prequalification promote vaccine security in general and particularly in the context of LTAs and AESOPs?
- Group 6. What additional information, tools or systems are needed in endemic settings, other than the number of vaccines required, for ensuring appropriate vaccine supply for FAST diseases, and how can these best be identified and collected?

The groups presented their findings highlighting the main points of their discussion, the conclusions and recommendations.

Conclusions

Group 1. Four key barriers were identified to vaccine security: supply, national forward planning, and price and supply chain issues. There is a limited global capacity to manufacture high-quality vaccines and an inability to respond in an appropriate time frame for urgent situations. Veterinary authorities need to be better prepared to anticipate need and allocate appropriate resources to address disease priorities and fund vaccination campaigns.

The price of quality vaccines was considered a major issue for LMICs and an inevitable impact on the number of doses that would be purchased and consequentially on the extent of vaccination. Supply chain issues were also considered a major issue given the need to maintain the cold chain from the manufacturing site through to the farm at the point of use.

Group 2. Group 2 explored the key differences between the FMD vaccine bank models, long-term supply arrangements (LTAs) or assured emergency supply options (AESOPs) and how can they best be used to improve vaccine security. It was agreed that more analysis was required to better understand the difference between antigen bank models and AESOPs, with the latter bridging emergency supply and long-term supply options. There was an acceptance that the risks had to be shared for safety stocks, especially for niche antigens for which the manufacturer may not be able to consume in routine production should there not be a call-off. The flexibility within long-term supply agreements also needed further development to offer purchasers the possibility of significant flexibility for their demand from year to year. Antigen bank models could also be more flexible than the classical model, offering bespoke models to best fit with the customer needs.

Group 3. The AESOP model needs some improvement to overcome problems such as insufficient stock availability and availability of a broad enough selection of strains. A regional approach or mutualization would be beneficial, and there is a requirement to utilize appropriate models to ensure good quality forecasting. There may be a benefit in investigating other fields, such as the systems used for human vaccines, or even other industries, such as the car industry, to gain insight into other functional models.

A recommendation was made for a (F2F) workshop with people with diverse experience and a wide knowledge base to facilitate thinking outside of the conventional veterinary vaccine box.

Group 4. VADEMOS has been developed as a decision-support tool intended to be used to estimate current and future vaccine dose demand for foot-and-mouth disease (FMD) at national, regional and global levels. VADEMOS uses predictors of vaccine dose demand such as livestock population growth forecast, disease control policy related to projected Progressive Control Pathway for FMD (PCP-FMD) stage, vaccination schedule and outbreak forecasting. There was an agreement that the tool could be further optimized to support veterinary authorities and manufacturers to better predict demand and manufacturing output. It was suggested that the market intelligence data on estimated demand for vaccine that are gathered by manufacturers, as well as actual sales for the previous years, could be

shared by the VADEMOS team of the EuFMD for the purposes of validation. It was noted that this will only be possible if most of the manufacturers could share their information in a way that won't be considered sharing commercially sensitive data. It was also suggested that additional features such as serotypes (or even lineages), the size of vaccine delivery (vials of FMD vaccine), and an economic module to provide an insight into the cost of production, purchase and delivery of vaccine could be added to VADEMOS. Participants agreed that the model could be adapted and applied to other FAST diseases such as LSD and PPR.

Group 5. It was agreed that quality is only one element but is an important foundation for developing the concept of vaccine security. Prequalification of vaccine (PQv) PQv fills a gap as quality is the essential basis on which all other elements are built. These include assurance of the supply chain (cold chain), antigenic relevance and vaccine selection and administration. Systems for quality assurance and standards exist, but purchasers do not have assurance that the systems and standards are actually applied. The problem is therefore one of trust. PQv needs to be a system that purchasers can trust in terms of assurance provided. It needs to strike the right balance on the level of rigour applied, for PQ needs to be carefully balanced to ensure it adds value without representing such a burden that manufacturers will not engage. For distributors of FMD vaccines, PQv provides assurance when vaccines are purchased from countries with less developed regulatory systems. Where the GMP status of the manufacturing site is unknown, PQv can act as an information resource and help educate and inform customers of the level of quality, supporting data and product literature they can reasonably expect to see when purchasing vaccine. For example, PQv is useful in providing assurance that the shelf-life stated on the label has been validated as the WOAH Terrestrial Manual is not prescriptive on the requirements. Ultimately, PQv needs to be linked to information on antigenic suitability of vaccine strains. Information that a vaccine is potent and high quality provides some support that it will in general have wide antigenic coverage, but there is still need for evidence that vaccine is relevant to circulating viruses, which is provided by reference laboratories.

Post-vaccination monitoring (PVM) needs to be linked to PQv as PVM remains essential even if PQv is applied. PQv provides the assurance that the manufactured vaccine itself is of high quality. Therefore, a root-cause analysis can be performed if there is a vaccine failure, which would not be possible without that assurance.

Group 6. There can be additional barriers to vaccine availability in endemic settings other than manufacturing considerations that prevent vaccination occurring where and when it is needed. There needs to be further consideration of the additional information, tools and systems that are needed for endemic settings, other than the number of vaccine doses, for ensuring appropriate vaccine supply for FAST diseases.

What systems and structures are needed in national and international animal health systems for ensuring appropriate vaccine supply for FAST diseases?

How do we ensure equity in partnerships that aim to increase vaccine security in endemic settings?

Recommendations

- Vaccination is a key-control measure for FMD control in endemic settings, and effective vaccination strategies must consider vaccine delivery. Vaccine delivery must be cost-effective, appropriate, timely and well managed for disease control to be achieved. There are a range of common policy and technical constraints that exist for FMD vaccination, especially in endemic settings, and it is recommended that an MSP further explores and identifies mechanisms to strengthen vaccine delivery.
- Further analysis and development are required to develop innovative business models to

improve the long-term availability and supply of FMD vaccines for FMD-free and endemic regions for various epidemiological scenarios. A further MSP workshop with experts from a diverse experience and a wide knowledge on business models in the pharmaceutical sector and other industries could facilitate novel approaches for FAST vaccines to make progress in the area.

- VADEMOS has been developed as a decision-support tool intended to be used to estimate current and future vaccine dose demand for foot-and-mouth disease (FMD) at national, regional and global levels. There was agreement that the tool could be further optimized to support veterinary authorities and manufacturers to better predict demand and manufacturing output and that a practical workshop should be held to identify improvements and get stakeholder input to ensure the practical benefits of VADEMOS. It was also suggested that additional features such as serotypes (or even lineages), the size of vaccine delivery (vials of FMD vaccine), and an economic module to provide insight into the cost of production, purchase and delivery of vaccine could be added to VADEMOS.
- Post-vaccination monitoring (PVM) needs to be linked to PQv, and an MSP platform could examine the systems that could link PVM and PQv to improve the quality of vaccines used in the field. Evidence to support the efficacy of FMD vaccines in heterologous cross-protection challenge tests in accordance with the WOAH Terrestrial Manual could be included at Stage 1 to provide additional information to risk managers to manage disease in various epidemiological scenarios. Vaccine matching or other antigenic characterization data from regional and national FAO and WOAH FMD reference laboratories or from manufacturers' own studies could also provide data to demonstrate the relevance of their FMD vaccine strains to circulating field strains.

CLOSING CEREMONY

The Director of FAO's Animal Production and Health Division (NSA), Thanawat Tiensin, highlighted that the OS22 represented a great contribution to the pathway to sustainable livestock transformation. In particular, he stressed the following aspects:

- Digitalization and innovations are tools that can help us in improving disease surveillance. Also, smartphone and mobile technologies are changing the way we develop and design our reporting and surveillance systems. Digitalization and innovations are also relevant for laboratory capacities enhancement.
- Recently, the FAO Science and Innovation Forum was initiated, with sessions on science and innovation for sustainable livestock transformation where EuFMD shared its experience on using epidemiological models to support EuFMD Members Nations, to improve prevention and control policies and strategies at country level, and to support to decision-making.
- He pledged participants to bring new ideas, innovations and knowledge gained from the OS22 conference back to their home countries to scale up and replicate the good initiatives at the country level for more impact.
- FAO NSA hosts the EuFMD and will continue to support its members toward a transformation of the livestock sectors for more sustainability, resilience, inclusiveness and efficiency.
- Finally, he informed all participants that on 4 November 2022, the FAO will launch the second phase of the PPR Global Eradication Programme (GEP) with the WOAH, so that eradication of PPR is achieved by 2030. Your support and engagement are needed.
- We would like to raise the profiles of the livestock sector, and on 7 December 2022, the high-level FAO event on preparedness and emergency in action: sustainable livestock transformation will take place, and the EuFMD will be invited to showcase its activities.

Conclusions

The OS of the European Commission for the Control of Foot and Mouth Disease was a unique opportunity for science and policy to meet and learn from the innovative and transformative solutions applied in the fight against FAST diseases. This event represents a great contribution to the way forward to sustainable livestock transformation.

The application of digitalization and innovation to disease prevention and control was the overarching theme of the OS. It is a well-known fact that FAST disease incursions can have devastating outcomes in disease-free countries, while controlling them in endemic areas can positively affect national economies, livelihoods of livestock keepers, reduction of antibiotic usage and animal welfare. Fighting FAST diseases therefore makes food production systems more efficient, resilient and sustainable, contributing to the achievement of the objectives of the FAO's Strategic Framework. Ultimately, this supports the 17 Sustainable Development Goals of the 2030 Agenda of the United Nations, with particular reference to SDGs 1 (No Poverty), 2 (Zero Hunger), and 10 (Reduced Inequalities), but also contributing to other SDGs 3 (Good Health and Wellbeing), 5 (Gender Equality), 8 (Decent Work and Economic Growth), 12 (Responsible Consumption and Production), 13 (Climate Action), 15 (Life on Land), and 17 (Partnerships for the Goals).

These are ambitious targets, as FAST disease surveillance and control are often expensive and logistically challenging. It is thus paramount to develop new approaches to rationalize resources invested while at the same time ensuring proper actions and the maximum impact of interventions. In this context, the role of inventive and emerging technologies is particularly important. In fact, technology, innovation, data, and complements represented by governance, human capital, and institutions have been identified by FAO as "cross-sectional accelerators" capable of increasing the impact of all their programmatic interventions.

All the themes addressed by the six sessions that constituted the OS provided answers and reflections

for achieving more efficient, inclusive, resilient and sustainable agrifood systems. Reducing the impact of clinical FAST diseases, or even eradicating them, can increase livestock productivity, thus improving access to food and livelihoods while at the same time ensuring more efficient use of natural resources with a lower environmental impact. The whole of human society, as well as livestock and the environment, can benefit from the positive outcomes deriving from the control of FAST diseases, from the perspective of a One Health strategy.

Policy makers, risk managers and scientists had the opportunity to discuss specific and relevant topics:

- **Session 1 – Emergency Preparedness and Response** explored how digital transformation is supporting animal health emergency preparedness and response and presented new technologies to assist more efficient information exchange and timely decision-making. Furthermore, we learned about successful stories of programmes that were able to deploy emergency response actions in times of the COVID-19 pandemic by combining virtual and face-to-face interactions. Ensuring the continuation of a timely response is essential to achieve resilience of livestock to crises, better production and better use of resources.
- **Session 2 – Digital learning** covered the growing field of enhanced learning through digital technologies and remote peer-to-peer modalities that EuFMD pioneered back in 2013. Digital learning can increase access to capacity-building programmes by disadvantaged areas and categories, further contributing to better production and a better life with lower impact on the environment.
- **Session 3 – Virology and diagnostics** and **Session 4 – Vaccinology** discussed the recent advancements in FAST diagnostics and how improving our understanding of the immune response supports the design of better vaccines. The experts explored challenges and new technical and political strategies for improving design, production and availability of quality vaccines. Molecular epidemiology, diagnostics and vaccinology are characterized by the rapid development of technical innovative solutions. These fields clearly show the importance of investing in research and developing and maintaining a dialogue between the public and private sector to ensure application of new research outcomes.
- **Session 5 – Risk assessment and modelling** reviewed the increasing opportunities for data-driven actions with examples of advanced data analysis, disease modelling, risk assessment and forecasting and how these approaches can be used to inform decision-makers in a timely manner and adjust the allocation of resources.
- **Session 6 – Surveillance and control** explored the potential of digitalization and new surveillance and control strategies for FAST diseases, also taking into account the lessons learnt from the review of the recent strategies adopted in the fight against COVID-19 events. Replacing general surveillance and control strategies with interventions targeted to animals, sectors and regions at higher risk, as well as designing actions directed at multiple diseases presenting similar epidemiological traits and control solutions, can make a significant difference in terms of effective use of resources and determine the success of health programmes.

Today's challenges require cooperation across multiple disciplines, sectors, countries, and across the whole of society. The EuFMD has a long tradition of bringing science and policy into contact, working alongside national and international research institutions, national veterinary services, other international organizations, as well as the private sector, to favour uptake of technical knowledge by decision-makers. In this context, the biennial event represented by the OS was a successful example of cooperation in the quest for more efficient, inclusive, resilient and sustainable agrifood systems for better production, better nutrition, a better environment, and a better life.

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United Nations Sustainable Development Goals (UN-SDGs)

EuFMD's programme has a main focus on

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MOVE FAST

FAST, Foot-mouth And Similar Transboundary animal diseases.

EuFMD Committees

Executive Committee, Standing Technical Committee (STC), Special Committee for Surveillance and Applied Research (SCSAR), Special Committee on Biorisk Management (SCBRM), Tripartite Groups.

Hold-FAST tools

AESOP, Assured emergency supply options.
EuFMDiS, FMD spread model.
GET PREPARED, Emergency preparedness toolbox.
GVS, Global Vaccine Security.
SIMEX Online, Simulation exercises.
Outbreak Investigation application.
Pragmatist, Prioritization of antigen management with international surveillance management tool.
PCP-FMD, Progressive Control Pathway for foot-and-mouth disease.
PCP-SO, Support Officers.
RTT, Real Time Training.
SAT-PCP, PCP Self-Assessment Tool.
SMS Disease reporting.
SQRA toolkit, A method for spatial qualitative risk analysis applied to FMD.
TOM, EuFMD training management system.
VADEMOS, Vaccine Demand Estimation Model.
VLC, Virtual Learning Center.