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PPR Global Research and Expertise Network (PPR-GREN): 3rd Meeting

Report of the virtual meeting
9–12 November 2020



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List of acronyms

AU-PANVAC	Pan African Veterinary Vaccine Centre of African Union
CIRAD	Centre de coopération internationale en recherche
DIVA	differentiation between vaccinated and infected animals
ECO-PPR	Epidemiology and Control of PPR
FAO	Food and Agriculture Organization of the United Nations
GF-TADs	Global Framework for the Progressive Control of Transboundary Animal Diseases

PPR	peste des petits ruminants
PPRV	peste des petits ruminants virus
PPR-GCES	PPR Global Control and Eradication Strategy
PPR-GEP	PPR Global Eradication Programme
PPR-GREN	PPR Global Research and Expertise Network
OIE	World Organisation for Animal Health
SDGs	Sustainable Development Goals



Introduction

Peste des petits ruminants (PPR) is currently one of the most serious livestock diseases worldwide. Since the early 2000s, it has manifested itself as the main killer of sheep and goats in all areas where it is endemic: Africa, the Middle East and a large part of Asia. Over the past three years, it has threatened the populations of many wild small ruminants in Asia. Taking into consideration the importance of sheep and goats to the livelihoods of small farmers, the Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE) launched the PPR Global Control and Eradication Strategy (PPR-GCES) with the view to eradicating PPR by 2030. This strategy was adopted in 2015 at an international conference in Abidjan under the umbrella of the Global Framework for the Progressive Control of Transboundary Animal Diseases (GF-TADs). In 2017, organisers put together a first five-year PPR Global Eradication Programme (PPR-GEP) to implement the PPR-GCES, with the support of a PPR Secretariat and strategic guidance from the PPR Advisory Committee.

The biological factors that made it possible to eradicate rinderpest are also applicable in the case of PPR. The causal virus is very fragile and requires close contact between natural hosts for efficient transmission; no vector for viral transmission exists; there is an absence of known carriers; an efficient vaccine is available and provides lifelong immunity; and diagnostic tests are readily available.

The PPR-GCES encourages vaccination and surveillance, and supports research to improve the efficiency and timeliness of the former. To that effect, the PPR Global Research and Expertise Network (PPR-GREN) was established in 2018 at a meeting in Vienna, Austria. PPR-GREN acts as technical adviser to the PPR-GEP Secretariat and the PPR Advisory Committee. The objective of the PPR-GREN is to build strong partnerships between researchers and thereby stimulate PPR research and foster the improvement, development and transfer of new tools to appropriate users to support the implementation of the PPR-GEP.

At the launch of PPR-GREN in 2018, the members of its first Bureau were elected for a tenure of two years with the option for one renewal:

- *Chair*: Adama Diallo (Centre de coopération internationale en recherche [CIRAD])
- *Members*: Amanda Fine (Wildlife Conservation Society), Barbara Wieland (International Livestock Research Institute), Jeremy Salt (GALVMed) and Hamid Varshovi (Razi Vaccine and Serum Research Institute).

At the second GREN meeting, held in 2019 in Nairobi, Kenya, four thematic working groups were formed to study and provide recommendations in four respective topic areas:

- *atypical hosts*: understand roles and connections (Catherine Herzog and Abdelmalik Khalafalla);
- *wildlife*: understand epidemiology at the wildlife–livestock interface, reduce risks of PPR for and from wildlife (Camilla Benfield);
- *socio-economics*: understand the impact of PPR on different stakeholders, generate evidence to inform policy (Pacem Kotchofa and Nicoline de Haan);
- *vaccination strategy*: understand vaccines, epidemiology, modelling and aspects of human behaviour and social science (Bryony Jones, Mohd Saddam Bintarif and Nimmo Gicheru).

The overall aims of these groups are to improve vaccines, diagnostic tools and epidemiologic methods and to highlight other topics relevant for the efficient control and eradication of the disease. Group members will:

- a) update the GREN and GF-TADs on research outputs in their respective expertise areas;
- b) advise on research priorities to support the PPR-GEP.

The groups are expected to communicate with each other outside the annual PPR-GREN meetings.

After the first and second meetings, the third PPR-GREN was planned to be held in Qingdao, People's Republic of China, in November 2020. Because of the COVID-19 pandemic, FAO and the OIE, in agreement with the Ministry of Agriculture and Rural Affairs of the People's Republic of China, decided that the meeting would be held by videoconference from 9 to 12 November 2020.



Meeting objectives

At that current meeting, closely co-organised by the PPR-GREN Bureau, the PPR Secretariat and the thematic working groups, the thematic groups reported research results in their respective areas of expertise. Their

suggestions and recommendations will inform the development of the second phase of the PPR Global Eradication Programme (PPR-GEP II), which is to be implemented in 2021 and to be launched in 2022.

Meeting outcomes

The agenda of the meeting is provided in Annex I.

Copies of all contributions presented at the meeting will be made available on the GF-TADs website.

Opening ceremony

The meeting was attended by about 147 participants.

It was officially opened by Dr Matthew Stone, Deputy Director General of International Standards and Science, OIE, and Dr Henning Steinfeld, Officer-in-Charge of the Animal Production and Health Division, FAO.

Dr Stone described PPR-GREN as a community of scientists interested and engaged in implementing and supporting the PPR-GEP. The respective expertise domains and experiences of the meeting participants are important for the PPR-GEP, and all stakeholders have something to learn from this forum. He emphasised that, during the operational implementation of PPR-GEP, it is important that research and development, intelligence and experiences from the field continue to be used to fine-tune national programmes. He further asserted that a single and clear purpose – the global eradication of PPR – can only be achieved through cooperation and collaboration.

Dr Steinfeld informed participants that a new PPR resolution was adopted at the 28th session of the FAO Committee of Agriculture in October 2020. The resolution was approved by the Council in December 2020 and endorsed at the 42nd FAO Conference in June 2021. Dr Steinfeld highlighted the importance of GREN, stating that without research it will not be possible to eradicate PPR. The eradication of rinderpest required innovation and data-driven approaches; similarly, the role of researchers

will be fundamental for achieving global freedom from PPR by 2030. Meeting this goal will significantly contribute to achieving the UN Sustainable Development Goals (SDGs).

Dr Adama Diallo, Chair of the PPR-GREN, recalled the conclusions of the 2019 meeting, in particular the organisation of the PPR-GREN into thematic working groups. He presented a summary of the PPR-GREN Bureau activities during 2020:

- meetings with the PPR Secretariat;
- preparation of the PPR-GREN III meeting;
- participation by the Chair in the PPR Monitoring and Assessment Tool Review;
- participation in the fourth meeting of the PPR Advisory Committee.

Two recommendations made at that Advisory Committee meeting relate to the roles that GREN is expected to play:

- to serve as a source of experts for the PPR Secretariat and provide operational and technical support to countries implementing their national strategic plans;
- to be part of the group of experts that will draw up national and regional roadmaps towards verified global PPR eradication.

These recommendations are in line with the PPR-GREN vision to eradicate PPR. To that end, GREN is structured into working groups to highlight various fields of expertise as sources of technical support for the PPR Secretariat at the global level. At the local level, GREN will support countries in forming and implementing their PPR eradication programmes.

The Advisory Committee Chair, Prof. Mark Rweyemamu, welcomed the participants to this meeting and informed them of the main outcomes of the last Advisory Committee meeting held virtually in July 2020. The full report is being made by the PPR Secretariat.

The PPR Secretariat provided its activity report, updating attendees on the PPR-GEP implementation, including:

- the main recommendations of the fourth Advisory Committee meeting;
- the Lake Chad epizone meeting that was held in December 2019 in Yaoundé, Cameroon;
- the establishment of the PPR National Strategic Plan Repository;
- the implementation of the PPR Monitoring and Assessment Tool Review process;
- an update on resource mobilisation for PPR-GEP;
- an update on the current PPR epidemiological situation, which affects 58 countries plus one zone that are officially PPR-free.

The PPR Secretariat conveyed the following main messages:

- There is strong international consensus for eradicating PPR by 2030 as a contribution towards the UN SDGs. The FAO and the OIE remain committed.
- Significant achievements have been made with the National Veterinary Services, the stakeholders and the regional economic communities, but better coordination and vaccination policies based on epidemiology are still needed.
- The current funding gap in the PPR-GEP indicates the need for better mobilisation of resources and effective communication with donors and development partners.
- Coordination at the global level, especially between the PPR-GREN and the scientific community, is essential for dealing with emerging issues (e.g. PPR in wildlife).

Thematic group reports

After the opening ceremony and the presentations by the PPR-GREN Chair and the PPR Secretariat on the first day of the meeting, the two subsequent days were devoted to the activity reports of the thematic groups. The presentations of the PPR GREN Chair and the PPR Secretariat are available on the GF-TADs website.

Atypical Hosts Group

For better communication between members, the Atypical Hosts Group created a WhatsApp group message thread in January 2020. The group coordinated with the PPR Secretariat to request camel serum banks from

several countries. These banks are to be used to validate diagnostic PPR tests for that species. Meetings to secure access to these serum banks are ongoing.

The speaker presented an update on current knowledge regarding PPR virus (PPRV) infection in susceptible domesticated animal species other than sheep and goats, such as camels, pigs, buffalo and cattle. Antibodies against PPRV have been detected in camel and cattle sera in multiple locations. Antigen has also been detected in camel and cattle. Researchers infected camel, pigs and cattle in experimental settings. While previous reports had indicated that PPRV might cause respiratory disease in camels, two 2019 publications resulting from these experiments suggest camels are a dead-end host (1, 2). Pigs were previously considered insensitive to PPRV, but a 2018 report on the experimental infection of pigs (3) indicates high susceptibility in this animal species. Experts call for other studies to be carried out to identify conditions of PPRV pathogenicity and transmission in pigs and other suids.

Two publications (2, 4) describe the cattle experimentally infected with PPRV. Couacy-Hymann *et al.* used all four PPRV lineages in N'dama cattle (4). Schulz *et al.* used lineage IV Kurdistan isolate in three Holstein Friesian cattle (2). In these experiments, no clinical signs or onward transmission were observed in goats that were in contact with the infected cattle. The cattle demonstrated seroconversion.

Finally, the presenter updated attendees on cattle-to-goat transmission trials being conducted in Ethiopia. Natural transmission from intranasally inoculated goats to exposed sentinel cattle was demonstrated: cattle seroconverted but showed no clinical signs. Trials were expected to be complete in early to mid-2021. Results will be reported at the next PPR-GREN meeting.

Wildlife Group

Members of this group presented the PPR wildlife outbreaks and new research over the past two years. Until recently, PPR outbreaks in wildlife, with clinical expression of disease, were reported only in the Middle East and Asia. In Africa, the circulation of PPRV in wildlife populations was reported based only on serological findings, but in 2019 the first clinical case was reported in a Dorcas gazelle in Sudan (5). Moreover, PPR was recently confirmed to threaten critically endangered populations of wild ruminant species such as the Mongolian saiga antelope in Mongolia.

The Wildlife Group presented a new project, a Global Challenges Research Fund Global Research Translation Award project entitled 'Development of multispecies validated serology protocols for complex ecosystems, focused on East Africa, in support of Global PPR eradication'. It has the following objectives:

- a) Advance the Global Challenges Research Fund PPR serology by optimising test protocols for wildlife serum samples.
- b) Establish a regional PPR research laboratory in Eastern Africa with appropriate serological tests for multiple domestic and wild host species, including atypical hosts.
- c) Study seroprevalence of PPRV in African buffalo and Grant's gazelle in the Greater Serengeti ecosystem, and perform an epidemiological analysis of spillover versus spread.
- d) Publish these results and propose to PPR-GREN a new standard for serological surveillance and diagnostic interventions in complex ecosystems, to be considered for the revision of the GEP.

The group also presented updated guidelines for the control and prevention of PPR in wildlife populations. These guidelines have been approved by both FAO and the OIE and are published on the [FAO](#) and [OIE](#) websites.

The group highlighted reasons that the PPR-GEP and national strategic plans must consider wildlife. They identified knowledge gaps in the epidemiology of PPR and needs to:

- a) study the role of wildlife and the wildlife–livestock interface in the epidemiology of PPRV, including with molecular epidemiological studies;
- b) evaluate diagnostic serological tests in wildlife;
- c) establish a biobank of wildlife samples, including samples for molecular studies;
- d) establish an epidemiological database of suspected cases in wildlife;
- e) perform socio-economic studies of PPRV that include wildlife in order to frame and quantify the benefits of eradicating PPR within the bigger picture, including within One Health and the UN SDGs, thereby helping to mobilise resources and political will towards eradication efforts.

Finally, the group reiterated the need to thoroughly investigate suspected outbreaks of PPR in wildlife based on the approved guidelines. Investigations should retrieve field epidemiological and laboratory data, with full PPRV genomes if possible, to compensate for the current scarcity of PPRV genomic data from wildlife. The group advocated for targeted surveillance in key ecosystems to estimate the significance of conservation and the extent of the wildlife–livestock interface.

Socio-Economics Group

To generate greater awareness of and support for the PPR-GEP, the Socio-Economics Group focuses on PPR impact studies. These studies are aimed to highlight the impacts of the disease across settings and to make the economic

case for PPR eradication. Group members generate evidence that supports decision-making and fundraising activities for its political dialogue. In their presentations, group members provided updates on the latest socio-economic studies of PPR and related methodologies, including the social accounting matrix, system dynamics modelling and the participatory disease approach.

A social accounting matrix study was carried out regarding the effects of PPR in Ethiopia; its results indicate a reduction in agricultural GDP by 0.47% and a loss of nearly 220,000 jobs due to PPR. Measuring disease impact is important for quantifying losses and informing decision makers. However, data tends to be limited and available only in a very disaggregated form, making it difficult to accurately estimate impact.

The group next presented approaches for animal health modelling that account for the complexity of animal value chains. These approaches are used in the European Commission and in the Epidemiology and Control of PPR project (ECO-PPR), which is being implemented in East and West Africa with support from the International Fund for Agricultural Development. The project is led by the International Livestock Research Institute in collaboration with the CIRAD, the Royal Veterinary College and other national partners. Various teams are studying participatory disease modelling, including one team in Senegal from the CIRAD and the International Livestock Research Institute operating under ECO-PPR, as well as a CIRAD team in Nigeria operating under the Livestock Disease Surveillance Knowledge Integration project.

It is expected that those studies will increase what is known about the impact of PPR and the economic benefits of eradicating the disease. In addition, the studies will improve vaccination strategies towards the final goal of the PPR-GCES, PPR eradication.

Vaccination Strategy Group

In line with the messages of the Socio-Economics Group, the Vaccination Strategy Group reported the following updates on PPR vaccines and vaccination, diagnostic tests, molecular epidemiology and modelling.

PPRV strains are classified into four lineages based on their genome sequences. The two widely used live attenuated PPR vaccine strains, PPRV Nigeria 75/1 and PPRV Sungri 96, belong to lineages II and IV, respectively. Both vaccines have been demonstrated to protect against infection from all four lineages of PPRV. They are effective by both subcutaneous and intranasal routes (6). New versions of these two PPR vaccine strains that enable the differentiation between vaccinated and infected animals (DIVA) have been developed at the Pirbright Institute. These versions have been patented and given to two

vaccine companies for commercialisation. Other potential DIVA PPR vaccines are also available, including recombinant vaccines based on capripoxvirus, Newcastle disease virus and adenovirus. These vaccines are used as vectors carrying the PPRV F and H genes, which encode the viral proteins that induce protective immune responses in vaccinated animals.

The current live attenuated PPR vaccines are heat sensitive, and several laboratories are studying how to improve their thermotolerance. The Pan African Veterinary Vaccine Centre of African Union (AU-PANVAC), the OIE Collaborating Centre for the quality control of veterinary vaccines, has prescribed a minimum requirement for PPR thermotolerant vaccines to be resistant at 40° C for five days.

New tests are currently available for PPR diagnosis, including a test based on loop-mediated isothermal amplification, and a PCR multiplex for the simultaneous detection of nucleic acid from many small ruminant pathogens in less than one hour. The latter has the potential to be used in the field as it can be run on a portable nucleic acid amplification platform (7).

The group highlighted the importance of molecular epidemiology to enable tracing back PPR outbreaks to their origins and to help in disease surveillance and control. Full genome sequencing data linked with epidemiological data will provide reasons for the PPRV spatial changes that have been recorded in various locations. For example, lineage IV is expanding rapidly in Africa, while lineage I has nearly disappeared. The reason for this change is unknown and should be researched. Virus pathogenicity studies are also needed, in particular to explore the variations in virulence of PPRV among different host species, including wildlife and domestic atypical hosts. Such information might help in refining control strategies.

The best samples to be used for PPR diagnosis are nasal swabs, followed by ocular swabs.

For sample testing, the following FAO/OIE PPR reference laboratories are available to provide support, including advice on which tests should be used: the CIRAD in France, the Pirbright Laboratory in the United Kingdom and China Animal Health and Epidemiology Centre in the People's Republic of China.

The group identified the following topics for further research:

- a) changes in the geographic distribution of PPRV lineages;
- b) livestock movement patterns, and implications of heterogeneity of contact for PPR transmission and vaccination;
- c) evaluation of the various vaccination delivery approaches to gather evidence for further upscaling, especially in remote areas;
- d) development of a system for recording data regarding vaccine doses that would improve forecasting methods to meet the field demand;
- e) modelling of PPR epidemiology to inform PPR eradication strategies.

Discussion themes

After the working group presentations and discussions, in the next part of the meeting, participants discussed three themes with the aim of producing recommendations for the expert group that will develop the PPR-GEP II. The themes were (a) **Vaccines, surveillance and vaccination strategies**, (b) **Socio-economics** and (c) **Wildlife and atypical hosts**. For each session, participants broke out into eight groups. Each session lasted for 15 to 20 minutes, after which time participants were automatically transferred back to the plenum. The tasks for each group in a session were:

- to review the conclusions and recommendations for GEP based on the thematic groups' activity reports;
- to add other recommendations and ideas as needed;
- to record as many details as possible.

SESSION 1: VACCINES, SURVEILLANCE AND VACCINATION STRATEGIES

Participants identified issues that might delay PPR eradication. The areas needing improvement are as follows:

- *In surveillance:*
 - local knowledge of small ruminant diseases; understanding and acceptance of vaccination;
 - development of multiplex assays; their promotion for use for PPRV differential diagnosis in national and local labs; their adaptation to field use;
 - data on livestock movement patterns, for molecular epidemiology and network analysis;
 - case studies of different vaccination delivery system approaches, including evaluation of vaccination efficacy;
 - assessment and improvement of vaccine supply chains and distribution, especially for less-accessible areas;
 - livestock keeper willingness to vaccinate and to pay for vaccination (if appropriate) in various contexts;
 - methods for capturing data on the number of animals vaccinated for monitoring and planning;
 - causes of vaccination failure.
- *In molecular epidemiology:*
 - full genome sequencing notably from Africa and the Middle East, including ancient strains and those from wildlife and atypical hosts (archived samples can be sampled to fill gaps in the historical record);

- matching full epidemiology data with genome sequencing data for better representation of PPRV strains, both spatially and temporally;
- understanding changes in the spatial and temporal distribution of PPRV lineages (in particular the lineage IV expansion) and linking PPRV molecular data with production systems, epizones, animal movements and trade.
- *In vaccines:*
 - continued development and assessment of thermotolerant PPR vaccines (standard operating procedures, including minimum criteria, to be finalised by AU-PANVAC);
 - field trials of intranasal vaccines – monitoring ease of use and efficacy under field conditions compared to subcutaneous administration;
 - assessments of the effectiveness of current PPR vaccines in camels and endangered wild species.
- *In modelling and vaccination strategies:*
 - meta-population models of local transmission and contact networks;
 - implications of population heterogeneity for PPR transmission and vaccination;
 - variance in model predictions depending on a relationship between transmission rates and population density;
 - modelling of various vaccination strategies in diverse production systems (pastoralist, agro-pastoralist, sedentary mixed farming);
 - mass vaccination, pulse vaccination, timing and frequency of vaccination.
 - age groups to be vaccinated (Should young animals be excluded?);
 - targeted vaccination.

Recommendations for PPR-GEP II

Based on the above areas for further exploration and based on available resources, participants made the following recommendations for consideration in the development of PPR-GEP II:

- Put more focus on defining epizones for coordinating surveillance and vaccination. Epizones should be defined based on information on populations, communities, production systems, animal movements and trade.
- Strengthen surveillance systems to measure occurrence and distribution of PPRV, to monitor the programme and to determine high-risk areas for targeted surveillance and vaccination.
- Promote disease reporting by livestock keepers, animal health workers and field vets, by any method including mobile phones.

- Improve capacity for outbreak reporting, investigation and confirmation with rapid field tests, differential diagnosis and sample collection for laboratory confirmation.
- Strengthen capacities of laboratories for PPR-specific diagnosis and differential diagnosis.
- Stress the need for high-quality full genome sequencing representing all infected areas, notably for lineage IV in Africa, ancient strains and atypical hosts – together with associated epidemiology data.
- Stress the high importance of herd immunity analysis for evaluating the effectiveness of vaccination programmes and the need for good survey design for serological surveillance.
- Grow the participation of livestock keepers (male and female), communities and local leaders in the eradication programme. To this aim:
 - understand local priorities, the local disease situation and local terminology;
 - explain the control programme and agreeing roles, especially in disease reporting, vaccination planning and vaccine supply chains.
- Describe options for and perform case studies of vaccination delivery systems that can be adapted for each specific context:
 - public – centralised or decentralised
 - private
 - public–private partnerships
 - community-based
 - veterinarians, veterinary para-professionals, community animal health workers and vaccinators
 - payment or free-of-charge scenarios (consider incentives)
 - thermolabile/thermotolerant vaccines.
- Encourage finalising the development of PPRV DIVA vaccines, including field trials and commercialisation and their use to speed PPR-GEP II implementation.
- Determine the pros and cons of identifying vaccinated animals.
- Surveil and vaccinate sheep and goats at the wildlife–livestock interface to reduce risk for endangered species; sequence PPRV from cases in domestic and wild animals to show possible direction of transmission and inform epidemiology.
- Determine PPR vaccine dosage and effectiveness in camels before considering whether to implement camel vaccination.
- Appoint quality-control of PPR vaccines by independent institutions: AU-PANVAC in Africa and eventually another FAO/OIE-designated institution in Asia.

SESSION 2: SOCIO-ECONOMICS

The following topics need a clarified understanding:

- *PPR control and eradication approaches:*
 - strategies that would be best suited for surveillance and control in each location;
 - ways to link the socio-economics of PPR to the epidemiology to enable better targeting of control strategies.
- *Socio-economic evidence to support decision-making:*
 - more socio-economic impact studies and frameworks to enhance awareness among high-level decision makers and encourage them to allocate local funds and reduce the impact of PPR in their communities;
 - benefit–cost ratios for PPR interventions;
 - the socio-economic impact of PPR in wildlife.
- *Importance of gender and age in PPR control and eradication strategies:*
 - ways to address the lack of accessibility to vaccines for all stakeholders, especially for women and youth;
 - in participatory modelling, designs for more gender- and youth-sensitive role-playing games.

Recommendations for PPR-GEP II

Participants recommended that:

- More social scientists and socio-economists should be involved in the development of the PPR-GEP II.
- Socio-economic surveys could be one of the mandatory activities under PPR-GEP II.
- Fundraising activities should support socio-economic studies.
- Socio-economic costs and unforeseen effects of controlling animal movement within and across regions should be considered in the PPR-GEP II budget.
- Socio-economic impacts of PPR in wildlife should be evaluated.
- Specific examples of control scenarios (with sufficient economic data) should be shared to support decision-making in other settings.
- Value chain barriers to vaccination should be identified.
- Private and public sectors should remain important actors in implementing the PPR-GEP.
- National and central veterinary agencies should be informed about the power of participatory methods and should be incorporated into national implementation plans.
- The various modelling approaches that were presented should be examined and applied to enhance the PPR-GEP II.

- Livestock movement patterns should be identified with regards to their implications for PPR control.
- Communities should be mobilised before starting the vaccination campaigns, in view to sensitise them and to ensure that as many farmers as possible will have their animals vaccinated.
- The willingness to pay for vaccination and the willingness to identify or mark vaccinated animals should be addressed.

SESSION 3: WILDLIFE AND ATYPICAL HOSTS

During this last session, participants discussed the following main topics: availability of evaluated assays for diagnosing PPR in atypical and wildlife animal species, and experiments to study the potential role of wildlife and atypical hosts in the epidemiology of PPR.

Participants identified the following research needs:

- *Atypical hosts:*
 - Determine which of the current diagnostic tests are suitable for detecting PPRV exposure via antibodies in atypical host species, leveraging existing sera banks where possible.
 - Include atypical host species in routine serological and molecular surveillance where these species are kept in proximity to small domestic ruminants; consider adding atypical domesticated host species to the OIE *Terrestrial Animal Health Code*, as well as organising a centralised, sero/molecular surveillance coordination centre.
 - Develop and disseminate clear guidelines for serological and molecular surveillance, primary interventions and control that can be tailored to the country settings where atypical host species mix (or have overlapping ranges) with small domestic ruminants; define which atypical host species may serve as sentinels if they are not targeted for vaccination.
 - Establish an international sharing platform for data, protocols and analysis pipeline standards in these species; standardise spreadsheets and databases with data dictionaries.
 - Conduct experimental and field research to determine whether these species shed infectious PPRV and under what conditions these species might transmit PPRV.
 - Establish more frequent and regular communication with the Wildlife Working Group to share best practices and lessons learned.
- *Wildlife:*
 - Concerning the role of wildlife and the wildlife–livestock interface in the epidemiology of PPR, enhanced surveillance and monitoring of

susceptible wildlife species, and both wild and domestic ungulates at interfaces, are critical for biodiversity and biodiversity-based economies. Investigations into the role of wildlife should include epidemiological role, potential for virus transmission, and role in disease surveillance in various settings. Results of that investigation will inform (i) whether wildlife may contribute to PPRV spread in livestock, (ii) the use of wildlife as sentinels of PPR in ecosystems and (iii) the threat posed by PPRV to the survival of endangered and threatened wildlife species (SDG 15).

Outcomes for PPR-GEP

1. Pursuing the above-mentioned research needs will inform targeted vaccination of livestock at the wildlife–livestock interface and support an approach that achieves optimised outcomes for human communities, their livestock and biodiversity.
2. With enhanced evaluation of diagnostic serological tests in wildlife, reliable tests will enable insights into epidemiology in atypical hosts.
3. A biobank of wildlife samples, including samples for molecular studies, will be established. This activity will include opportunistic sampling. Samples will enable research into PPR in wildlife including host susceptibility, virus evolution, pathogenesis, immunity and epidemiology. Information gathered from the samples will inform PPR-GEP strategy and help to assess the threat PPRV poses to biodiversity and functioning ecosystems.
4. The epidemiological database of suspected cases in wildlife will be improved, based on data from clinical reports and collated suspected cases.
5. Wider socio-economic studies of PPR that include wildlife will help to frame and quantify PPR benefits within the bigger picture, including One Health and the UN SDGs, thereby helping to mobilise resources and political will towards eradicating PPR.

Recommendations for PPR-GEP II

1. *Engage wildlife and veterinary agencies in PPRV eradication at the wildlife–livestock interface.*
 - 1.1: Include wildlife in PPR-GEP, regional strategies and national strategic plans.
 - 1.2: Advocate for better integration of wildlife in PPR-GEP.
 - 1.3: Engage wildlife agencies in planning and implementation.
 - 1.4: Standardise guidelines for PPR management in wildlife.
2. *Support wildlife diagnostic and surveillance systems.*
 - 2.1: Increase research on the epidemiological role(s) of wildlife and determinants of susceptibility.
 - 2.2: Standardise guidelines for PPRV diagnostic tools in wildlife.
 - 2.3: Improve wildlife health surveillance, including via ecological monitoring and participatory methods.
 - 2.4: Include wildlife in regional epidemiology and laboratory networks.
3. *Integrate PPRV control efforts.*
 - 3.1: Adapt vaccination and control strategies to the presence of susceptible and significant wildlife populations.
 - 3.1: Consider the entire community of susceptible hosts, wild and domestic.
 - 3.2: Jointly monitor the effectiveness of PPRV control measures in livestock and wildlife.
 - 3.3: Monitor overall impact on livestock, wildlife and ecosystem health.
4. *Ensure financial resource mobilisation for the wildlife components of national, regional and global strategies.*



Conclusions

In this meeting the presentations and discussions showed that significant progress has been made in disease surveillance, molecular epidemiology, vaccine development (both DIVA and thermotolerant vaccines) and diagnostic tests related to PPR. These advances must be translated into field activities. To do so, laboratory scientists and field workers need to increase communication among themselves so that each can be continuously learning from each other and updating their field and research activities to support the PPR-GEP. Dr Jeffrey Mariner insisted on the need to revise continuously the list of knowledge gaps to guide research activities and ensure that PPR-GREN is 'really a learning and flexible structure'. The following knowledge gaps were highlighted as needing to be addressed soon:

- The place of atypical hosts and wildlife in the epidemiology of PPR. We do not know the capability of wildlife, pigs or camels to maintain PPRV in the field and to transmit it back to sheep and goats.
- The need to vaccinate atypical host species in locations where PPR may have dramatic consequences. Such possibilities can be considered only once the effective vaccine dose for that species is determined.
- Serological tests for additional species. Serological tests for identifying PPR antibodies have been validated only for sheep and goats. They must be validated for atypical hosts and wildlife if the disease is to be reliably monitored in those species. It is based on such tools that clear guidelines for PPR surveillance and control can be developed and disseminated.
- Socio-economic surveys to be developed for vaccination campaign monitoring and impact assessment.

Participants unanimously agreed that this virtual meeting was successful. They recommend repeating such events: communications within PPR-GREN should not be limited to the annual meeting, and more channels should be explored to strengthen mechanisms of communication within the network. The aim is to ensure engagement between annual events, to support collaboration among PPR-GREN actors that are implementing national strategic plans and to create an environment of ongoing dialogue between research experts and the actors in the field. It is suggested that between annual meetings, virtual meetings can be organised to address more specific topics, thereby maintaining the sharing of ideas between PPR-GREN and

other stakeholders involved in PPR eradication. In view of this, the Vaccination Strategy Group has suggested convening a virtual meeting on currently available PPR thermotolerant vaccines to discuss requirements and methods of evaluation.

The second PPR global eradication programme (PPR-GEP II) will be formulated by an expert group at the end of 2021, following the end of the first phase of the programme. The meeting participants have made recommendations for the expert group to consider in formulating the PPR-GEP II, and they insist that the core of this expert group should be PPR experts. The objective of PPR-GEP is to eradicate PPR rather than merely control it, as in the more complex case of foot and mouth disease.

Finally, participants accepted challenges highlighted by the PPR Secretariat for the successful implementation of the PPR eradication programme. They are as follows:

- **Advocacy:** National strategic plans are to be mainstreamed into national investment plans through socio-economic impact data.
- **Funding gap and political will:** Affected countries need to request resource partners for funding. Grant aid from donors is also needed.
- **Showcase of success stories:** Fifty-eight countries and one zone are recognised by the OIE as historically free of PPR. But no infected country has yet achieved freedom from the disease.
- **Harmonisation of control activities at the epizone level.**
- **Partnerships, including public-private partnerships:** Partnerships are needed among institutions, the Regional Economic Communities, value chain actors and national stakeholders for participating in the public-private partnerships.
- **Stakeholder awareness for PPR:** There is a need to create awareness and increase actors' involvement in PPR eradication.
- **Improving epidemiological understanding of PPRV:** Guiding mechanisms are needed to support countries in developing targeted PPR vaccination strategies informed by epidemiological and context assessments.
- **PPR vaccination campaigns:** The campaigns conducted by most of the countries are not in line with the PPR-GCES, in that they lack epidemiological assessment, are supplied with an insufficient number of vaccines or carry out inappropriate post-vaccination evaluation.

- **Post-vaccination evaluation:** should be conducted by countries to evaluate the effectiveness of individual vaccination teams using standardised guidelines.
- **Laboratory resources:** Reagents, infrastructure and access to laboratory consumables need to be strengthened. Guidelines must also be determined to define when and how to implement an appropriate range of diagnostic tests.
- **Small ruminant identification, registration and movement controls.**
- **Research gaps:** Gaps identified in previous PPR-GREN meetings include infection of wildlife and atypical species, socio-economic impact, DIVA and vaccine applicability in various hosts.

Recommendations to FAO and the OIE

Participants made their recommendations based on the following considerations:

- Knowledge of reliable disease surveillance results is essential for developing and implementing effective eradication activities.
- PPR is a transboundary disease.
- Like smallpox and rinderpest, PPR is a relatively simple disease to control. Tools are available for its global eradication.
- *Ad hoc* vaccination campaigns, carried out based on the availability of limited funding, will lead to repeated patchy vaccinations for many years without obtaining sufficient population sero-positivity and the objective of PPR eradication.

Recommendations to FAO and the OIE are as follows:

- Take appropriate actions to encourage countries to be transparent regarding their respective PPR situations, and promote information sharing.
- Promote strong cooperation at regional levels in activities for eradicating PPR, a disease of transboundary nature.
- Nominate PPR experts to form the core of the expert team that will write PPR-GEP II, and complement this core with experts from other fields.
- Support countries in finding funding for their PPR eradication programmes. It is important that when a country embarks on the PPR eradication programme, sufficient funds are available for its activities.

Next PPR-GREN Meeting: the 4th PPR-GREN Meeting

While the 4th PPR-GREN meeting was envisaged to take place in China in October 2021 in collaboration with the China Animal Health and Epidemiology Centre, due to the

ongoing pandemic situation, it will be held virtually from 6 to 8 December. It is to be organised by FAO and the OIE in collaboration with the PPR-GREN Bureau.

Closing ceremony

Dr Matthew Stone, on behalf of both FAO and the OIE, thanked the participants, congratulated the presenters for their excellent talks and thanked them for their engagement with the PPR-GEP. He indicated that the PPR-GREN seems to have come alive and matured significantly. He has no doubt that the information received during these four days of the meeting will help significantly in the development of the PPR-GEP II. The fundamental question is how to ensure that 'the GREN is fully embedded into the intelligence cycle of the PPR global eradication programme so that information that are received from the field are informing research activities'. He would like to see mechanisms in place to animate the PPR community and support collaboration among the experts and actors who are implementing national strategic plans in the field. He assured participants that both FAO and the OIE are promoting transparency by country. He noted the important questions that were raised regarding uncertainty around issues such as PPR epidemiology in wildlife and the importance of atypical hosts. Those questions

will have implications for the eradication stage of the PPR eradication pathway. He insisted that we need to manage expectations along the way and address these questions through well-structured research programmes and observational studies from the field. 'We need to prioritise our activities and focus on a systematic process of "One task at a time", taking into consideration some aspects of resourcing constraints'.

Dr Matthew Stone, Ms Anna-Maria Baka and Mr Felix Njeumi from the PPR Secretariat thanked the participants for their active engagement in the discussions. Attendees' level of participation during the plenary and the breakout sessions was beyond expectations. They congratulated participants for the work they had done before and during the meeting. They thanked the PPR-GREN Bureau and the working groups for organising this meeting in close collaboration with the PPR Secretariat.

Mr Adama Diallo, Chair of the PPR-GREN Bureau, concluded the meeting on the Bureau's behalf. He thanked the participants and the technical support staff who contributed to making the meeting a success.

Acknowledgements

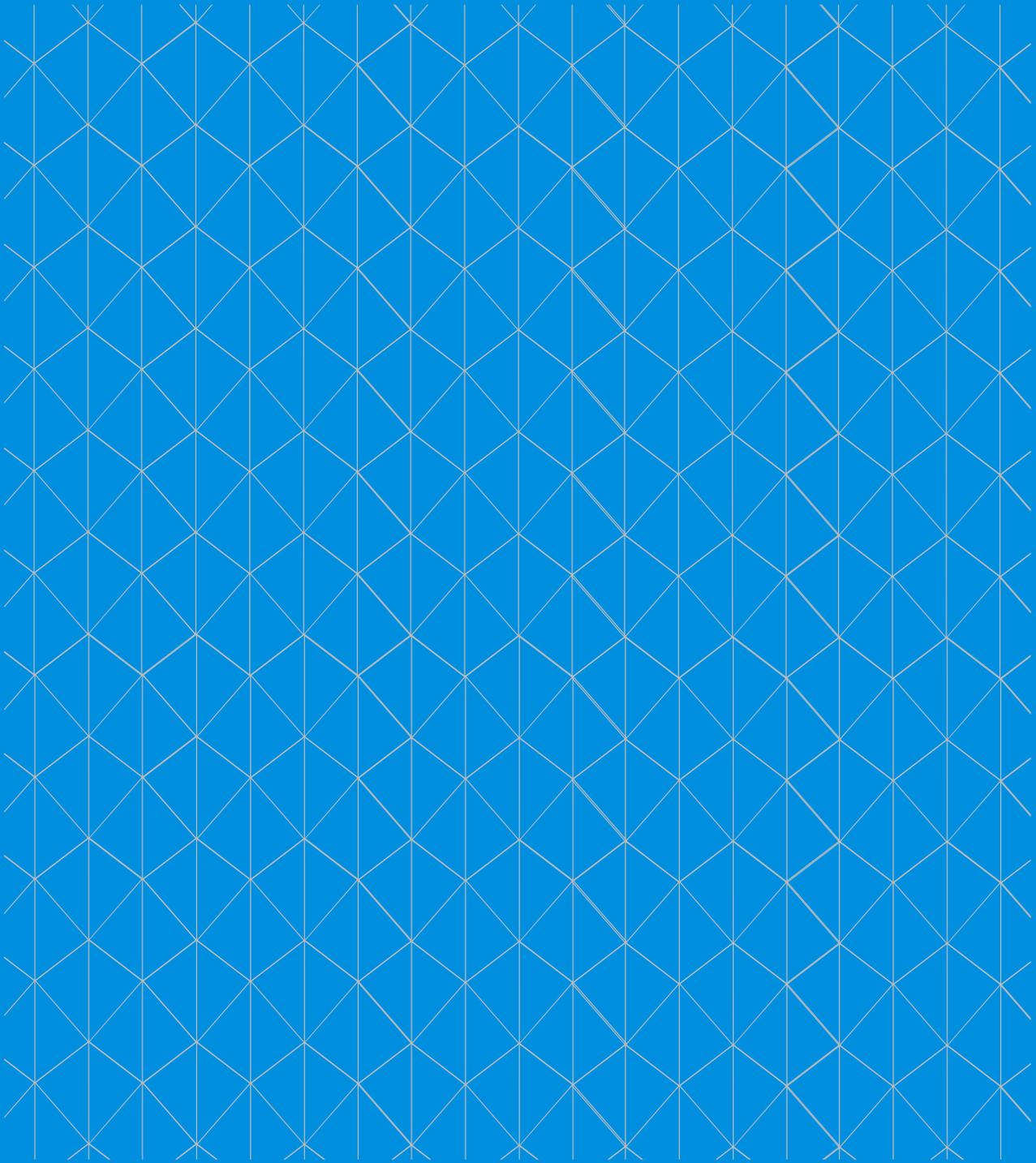
The participants acknowledge and appreciate the strong and consistent support of the management of FAO and the OIE to the PPR-GREN.

They thank the FAO staff who supported the PPR Secretariat, PPR-GREN Bureau and PPR-GREN working groups in organising this successful meeting.

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Annex



Concept note and agenda

BACKGROUND

Peste des petits ruminants (PPR) is one of the most current serious animal diseases. Indeed as of early 2000s it has appeared as the main killer of sheep and goats in all areas where it is endemic: Africa, the Middle East and a large part of Asia. In the past three years, it has been threatening regularly population of many wildlife small ruminants in Asia. Taking into consideration the importance of sheep and, in particular, goats in the livelihood of small farmers, the Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE) launched in 2017 a first programme to implement the PPR Global Control and Eradication Strategy (PPR-GCES) that was adopted at international conference in 2015 in view to eradicate the disease by 2030. Indeed, apart from the required resource funds, all biological attributes that have made possible the eradication of rinderpest are also available for PPR: need of close contacts between natural hosts for efficient transmission of the causal agent that is very fragile, number of natural hosts very limited, no vector for pathogen transmission, availability efficient vaccine providing lifelong immunity, absence of carrier, availability of specific diagnostic tests. In the GCES, in addition to the vaccination and surveillance activities, it is foreseen to encourage and support PPR research activities as companions to the former activities in view of improving their efficiency and speeding up their course. To that effect, the Global Research and Expertise Network (PPR-GREN) has been put in place in 2018 to foster and to stimulate exchanges between scientists and other stakeholders interested/involved in the PPR Global Eradication Programme (PPR-GEP). It is planned to hold a PPR-GREN meeting each year. After the first and second meetings that were held successively in Vienna, Austria, and Nairobi, Kenya, in 2018 and 2019, the third PPR-GREN was planned to be held in Qingdao, People's Republic of China, in November 2020. Unfortunately, because of the current COVID-19 pandemic, FAO and OIE, in agreement with the Ministry of Agriculture and Rural Affairs of China, have decided that PPR-GREN meeting be held by videoconference from 9 to 13 November 2020.

MEETING OBJECTIVE AND EXPECTED RESULTS

One of the outputs of the 2019 PPR-GREN meeting was the organisation of the network into four thematic groups: atypical hosts, wildlife, socio-economics and vaccination strategy (vaccines, epidemiology, modelling and human behaviour/social forum) working groups. The objectives of the groups are to: (i) update GREN & GF-TADs on research outputs in their respective expertise areas, (ii) advise on research priorities.

At the third PPR-GREN meeting, thematic groups will update participants on research in their respective expertise areas. It is expected that follow up discussions to those updates with their conclusions will contribute to the revision of the GEP that is planned to take place in 2021.

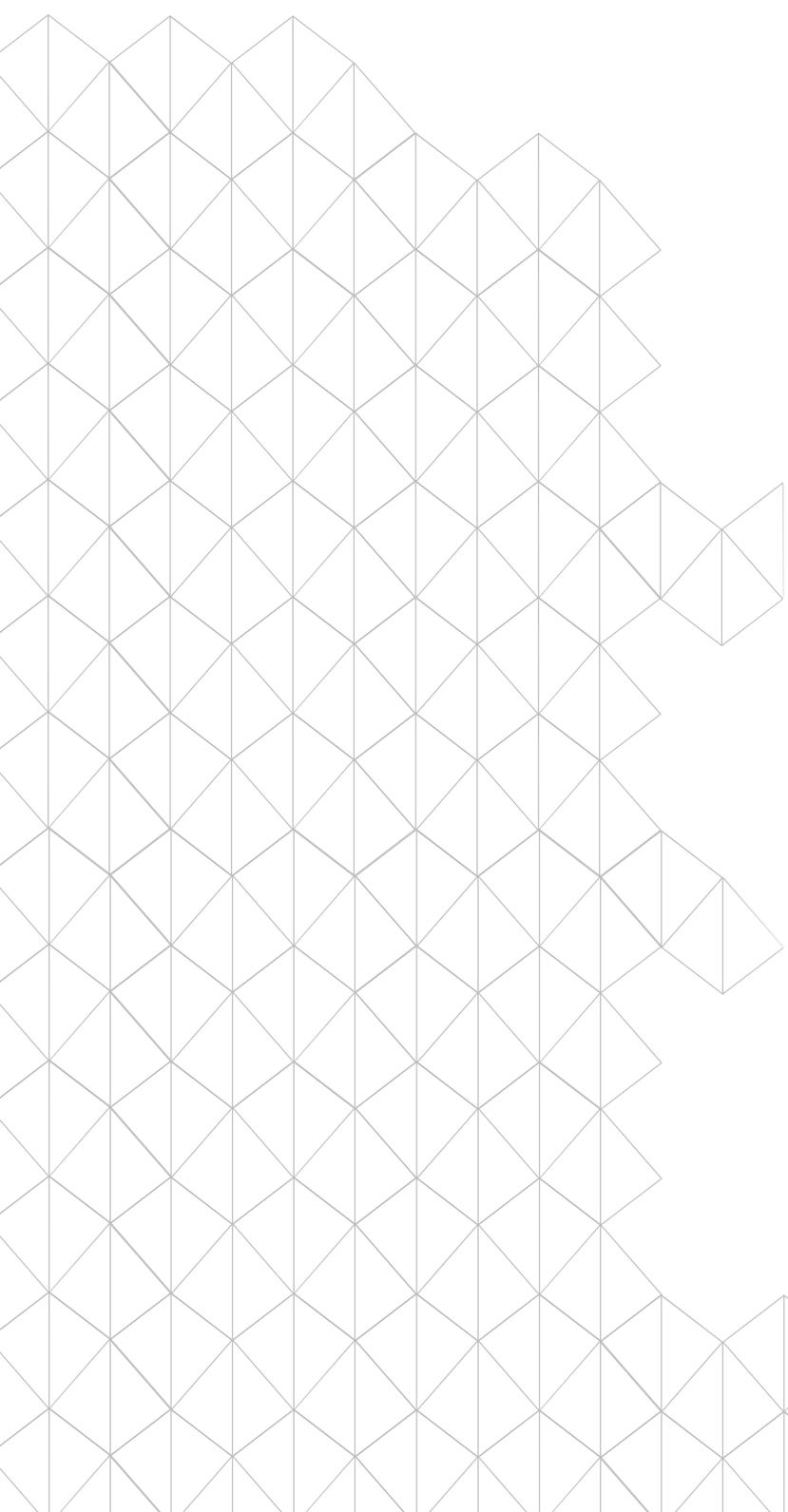
EXPECTED PARTICIPANTS

Expected meeting participants include representatives from the following:

- research institutions including the three PPR World Reference Laboratories (CIRAD from Montpellier, France, the Pirbright Institute from the United Kingdom and the Centre for Animal Health and Epidemiology, Qingdao the meeting's host institution) and many national veterinary research institutes in developing countries;
- the African Union Interafrican Bureau for Animal Resources and the Pan African Veterinary Vaccine Centre of African Union;
- the Wildlife Conservation Society;
- GALVMed;
- regional epidemiology and laboratory networks;
- the International Livestock Research Institute;
- PPR experts;
- PPR vaccine producers;
- resource partners;
- the Joint Food and Agriculture Organization (FAO) and International Atomic Energy Agency Division, including its Association of Public Health Laboratories
- FAO and World Organisation for Animal Health (OIE) headquarters;
- PPR Advisory Committee members;
- PPR-GREN Bureau;
- PPR Secretariat.

AGENDA

Day 1		
Time	Topics	Speakers
12.00 – 14.00 GMT	<ul style="list-style-type: none"> • Welcome address of OIE • Welcome address of FAO • Follow up of 2nd PPR-GREN meeting and objective of the 3rd meeting • PPR-GEP Advisory Committee Report • PPR Secretariat Report • Discussion 	<i>OIE Representative</i> <i>FAO Representative</i> <i>PPR-GREN Chair</i> <i>PPR-GEP AC Chair</i> <i>PPR Secretariat</i> <i>All participants</i>
Day 2		
12.00 – 13.00 GMT	<ul style="list-style-type: none"> • Thematic Atypical Hosts Group report • Discussions 	<i>Group focal point</i> <i>All participants</i>
13.00 – 14.00 GMT	<ul style="list-style-type: none"> • Thematic Wildlife Group report • Discussions 	<i>Group focal point</i> <i>All participants</i>
Day 3		
12.00 – 13.00 GMT	<ul style="list-style-type: none"> • Thematic Socio-Economics Group report • Discussions 	<i>Group focal point</i> <i>All participants</i>
13.00 – 14.00 GMT	<ul style="list-style-type: none"> • Thematic Vaccination Strategy Group report • Discussions 	<i>Group focal point</i> <i>All participants</i>
Day 4		
12.00 – 13.00 GMT	<ul style="list-style-type: none"> • Contribution of GREN to PPR-GEP Revision 	<i>All participants</i>
13.00 – 14.00 GMT	<ul style="list-style-type: none"> • Conclusions/Recommendations 	<i>All participants</i>
14.00 – 14.30 GMT	<ul style="list-style-type: none"> • Closing Remarks 	<i>OIE Representative</i> <i>FAO Representative</i> <i>PPR Secretariat</i> <i>PPR-GEP Advisory Committee Chair</i> <i>PPR-GREN Bureau</i>



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