Universitat Autònoma de Barcelona

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Evaluación de brotes, impacto económico y vigilancia epidemiológica en zonas libres

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Certifica:

Que la tesis doctoral titulada "**Epidemiologia de la peste porcina clásica en Colombia. Evaluación de brotes, impacto económico y vigilancia epidemiológica en zonas libres**" presentada por **María del Pilar Pineda Ortíz** para la obtención del grado de Doctora en Veterinaria, ha sido realizada bajo su dirección y tutela en la Universidad Autónoma de Barcelona.

Y para que conste a los efectos oportunos, firma la declaración en Bellaterra (Barcelona) a los 15 de Julio de 2021.

Dr Jordi casal Fábrega

Director

María del Pilar Pineda Ortíz

Doctoranda

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TABLA DE CONTENIDO

LISTA DE ABREVIATURAS Y ACRONIMOS

AR:	Adjusted risk
CSF:	Classical swine fever
CSFV:	Classical swine fever virus
ELISA:	Enzyme-linked immunosorbent assay
EPI:	Effective probability of infection
ICA:	Colombian Agriculture and Livestock Institute – Instituto Colombiano Agropecuario
INVIMA:	National Drug and Food Surveillance Institute
OIE:	World Organisation for Animal Health- Organización Mundidal de Sanidad Animal
P^*:	Design prevalence
P^*_H:	Herd prevalence and
P^*_A:	Within-herd prevalence
PCR:	Polymerase chain reaction
POLFA:	Tax and customs police - Policia Fiscal y Aduanera
Porkcolombia:	Colombian Association of Pig Farmers – National Pig Farming Fund - Asociación Colombiana de Porcicultores – Fondo Nacional de la Porcicultura
PPC:	Peste porcina clásica
R_2:	Farm level prevalence in commercial farm
R_1:	Farm level prevalence in backyard premise
RR:	Relative risk
SeHi:	Sensitivity at farm level
STM:	Scenario tree model
VPPC:	Virus de la peste porcina clásica
Zone 1:	Free zone recognized by OIE
Zone 2:	Zone undergoing an eradication process

RESUMEN

La presente tesis doctoral tiene como objetivo incrementar los conocimientos sobre la epidemiologia de la peste porcina clásica en Colombia, con el fin de mejorar las actuaciones de prevención y control de la enfermedad que se llevan a cabo en el país.

En el primer estudio se realizó una caracterización de los 134 brotes de peste porcina clásica que ocurrieron entre 2013 y 2018, basados en la información del Servicio Veterinario Oficial – ICA. Los resultados reflejaron que los departamentos afectados tienen una alta proporción de predios traspatio (93.2%), siendo estos los más afectados por la enfermedad (127 brotes, 94.8%). El 84% de los brotes fueron detectados por vigilancia pasiva, reportados principalmente por productores y la red de sensores epidemiológicos. Los puntos críticos de los tiempos de respuesta ante los brotes fueron: el periodo entre la identificación de signos clínicos y la declaración oficial de brote (mediana 11 días, rango de 9 a 72 días) y el periodo entre la inspección veterinaria y la confirmación del laboratorio (mediana 15 días, rango 4-78 días). La entrada del virus a las explotaciones se atribuyó a la introducción de cerdos infectados (38%), ingresos de personas (37%), origen desconocido (13%) y otras vías como contacto en pastoreo con cerdos ferales y vehículos de transporte. El brote índice apareció en el municipio de Urumita – La Guajira cerca de la frontera con Venezuela, siendo el origen más probable la introducción ilegal de cerdos infectados desde Venezuela. Las tasas de ataque y mortalidad en las explotaciones fueron de 39% y 32% respectivamente y la mayor proporción de cerdos enfermos se presentó en animales de 2-6 meses de edad. Los signos clínicos más comunes identificados fueron fiebre (67%), incoordinación (54%) postración (52%). En el 73% de los brotes no se había vacunado contra PPC y el 17% estaban parcialmente vacunados. Se identificaron fallas en el proceso de vacunación como inmunización de animales en días previos recientes o posteriores a la presentación de signos clínicos. El análisis espaciotemporal mediante modelo de regresión poisson revelo dos conglomerados con alto riesgo, el primero y más grande de 2014-2016 tuvo un riesgo relativo (RR) de 13.4 que incluyó parte de los departamentos de Atlántico, Bolívar, Cesar, la Guajira, Norte de Santander, Magdalena y Sucre y el segundo conglomerado tuvo un RR de 9.6 en 2016 que incluyo el norte del departamento de Córdoba.

En el segundo estudio se valoró el impacto económico de 156 focos que se presentaron entre 2013 y 2020, basado principalmente en información del ICA y de la Asociación Colombiana de Porcicultores - Porkcolombia. Los resultados reflejaron que los focos causaron un costo total de US $10.2 millones, donde el costo de la enfermedad y actividades de control de brotes fue US $466.473 concentrados principalmente en visitas a predios vecinos y contactos, muerte de animales, pago de compensaciones por sacrificio y visitas a las granjas con brotes. El costo promedio por brote de las visitas a granjas afectadas y a predios vecinos fue US $395 y US $903 respectivamente, mientras que se gastaron US $83 en pruebas diagnósticas. En 37 brotes se realizó compensación de animales con un costo promedio por brote de $2.674. Sin embargo, el mayor costo fueron las medidas de control en granjas no afectadas, especialmente la vacunación ya que se vacunaron entre 23.000 y 235.000 explotaciones cada año con un costo anual medio de US $1.15 millones (US $8.5 por granja). El costo se concentró principalmente en la contratación de los vacunadores con un valor entre 0.8 a 1.2 millones anuales. Los brotes causaron pérdidas directas a los productores por muerte de animales por US $148.059, mientras que solo recibieron el pago de US $98.950 por el sacrificio de los cerdos en 37 brotes. El costo de control de movimientos fue de US $963 por brote. El costo total de la vigilancia en el área afectada fue de US $1.047.906 que incluye el valor de las visitas de vigilancia activa a lugares de alto riesgo y las visitas a predios para atender las notificaciones de PPC. En conclusión el costo anual de los brotes en Colombia fue más económico respecto a otros países, principalmente debido a que no se sacrificaron los animales en las explotaciones infectadas, pero por otra parte, las medidas aplicadas no han permitido la erradicación de la enfermedad.

La presencia de una zona endémica en el país supone un riesgo para la zona libre de infección, dado este riesgo, en el tercer estudio se evaluó la sensibilidad de la vigilancia activa y pasiva en granjas y mataderos para detectar granjas infectadas en 2 zonas: una reconocida como libre por la OIE (Zona 1) y otra en proceso de erradicación con suspensión de la vacunación (Zona 2)[1]. Se emplearon árboles de escenarios y modelos estocásticos para describir la estructura de la vigilancia y para determinar la probabilidad de detección de granjas infectadas. La sensibilidad del sistema para detectar la presencia de una única granja infectada en Zona 1 fue 31.4% (IC 95%: 7.2-54.1) y en Zona 2 fue 27.8% (IC 95%:6.4-55.1);

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[1] Reconocida también por la OIE como libre en mayo de 2021

en el caso de que hubiese 5 granjas infectadas la sensibilidad fue 85.2% (IC 95%:67.3-93.7) y 82.5% (IC 95%:62-92.9) respectivamente. La vigilancia pasiva en granjas presento mayor sensibilidad para la detección de una granja infectada en ambas zonas (22.8% en Zona 1 y 22.5% en Zona 2) respecto a los demás componentes. La probabilidad de detección fue mayor en granjas familiares/traspatio respecto a las comerciales. La vigilancia pasiva en mataderos tuvo una sensibilidad de 5.3% y 4.5% para la detección de una granja en las Zonas 1 y 2 respectivamente. La vigilancia activa en granjas presento una sensibilidad general entre 2.2% y 4.5%. Una de las razones por la cual la vigilancia pasiva puede ser más sensible es el monitoreo frecuente por productores y veterinarios que se realiza en una parte significativa de granjas y que debe permitir un reporte temprano. Sin embargo, el reporte por productores depende de que estos tengan en consideración la enfermedad, reconozcan los signos clínicos, tengan confianza en el veterinario o personal de contacto y haya transparencia en el proceso de reporte. Por tanto, es importante fortalecer factores que afectan la sensibilidad del sistema, como la capacidad de productores y veterinarios en la detección de signos clínicos y educarlos en la importancia del reporte.

SUMMARY

This dissertation aims to increase knowledge about the epidemiology of classical swine fever in Colombia, in order to improve the prevention and control of the disease carried out in the country.

The first study is a characterization of the 134 outbreaks of classical swine fever occurred between 2013 and 2018 according to the information provided by the Official Veterinary Service (ICA). The results are in accordance with the high proportion of backyard premises (93.2%) and this type of farms were the most affected by the disease (127 outbreaks, 94.8%). The eighty-four percent of the outbreaks were detected by passive surveillance, reported mainly by producers and by the network of epidemiological sentinels. Related to the time of response, the period between the identification of clinical signs and the official declaration of the outbreak had a median of 11 days with a range from 9 to 72 days) and the period between veterinary inspection and laboratory confirmation had a median of 15 days (range 4-78 days). The main routes of transmission of the virus were the introduction of infected pigs (38%), visits (37%), unknown origin (13%) and other routes such as grazing contact with feral pigs and transport vehicles. The index case appeared in the municipality of Urumita – La Guajira, near the border with Venezuela, the most likely origin being the illegal introduction of infected pigs from Venezuela. The attack and mortality rates were 39% and 32% respectively and the highest proportion of sick pigs occurred in animals aged 2-6 months. The most common clinical signs were fever (67%), incoordination (54%) and prostration (52%). In 73% of the outbreaks, animals had not been CSF vaccinated and in 17% were only partially vaccinated. Some failures in the vaccination process were identified such as immunization of animals just few days before or after the presentation of clinical signs. The spatiotemporal analysis using a poisson regression model revealed two clusters with high risk, the first and largest one was from 2014-2016 and had a relative risk (RR) of 13.4 including part of the departments of Atlántico, Bolívar, Cesar, la Guajira, Norte de Santander, Magdalena and Sucre and the second cluster had a RR of 9.6 included the north of the department of Córdoba in 2016.

The second study assessed the economic impact of 156 outbreaks that occurred between 2013 and 2020, based mainly on information provided by the ICA and the Colombian

Association of Pig Farmers (Porkcolombia). The outbreaks caused a total cost of US $10.2 million, where the direct cost of disease and outbreak control activities was US $466,473 concentrated mainly on inspection of affected, neighboring and contact farms, payment of compensation and direct costs of the disease. Visiting the affected and neighboring farms had an average cost per outbreak of US $395 and US $903 respectively, while US $83 was spent on diagnostic tests and US $963 on movement control per outbreak. In 37 outbreaks, animals were stamped out with an average cost per outbreak of $2,674. However, the biggest cost of the control measures was the vaccination of pigs: between 23,000 and 235,000 farms were vaccinated annually with an average cost of US $1.15 million per year (US$8.5 per farm). The cost was mainly due to the hiring of vaccinators with a cost between 0.8 to 1.2 million annually. The outbreaks caused direct losses to producers due to death animals of US $148,059. The control of movements had a cost of US $ 963 per outbreak. The total cost of surveillance in the affected area was US$1,047,906 which included the value of active surveillance in high-risk facilities and the inspections performed in farms reported as suspicious of CSF. In conclusion, the annual cost of the outbreaks in Colombia was cheaper than the cost described in other countries, mainly because animals from infected farms were not slaughtered, but on the other hand, the measures applied have not been enough efficient to achieve the eradication of the disease.

The existence of an endemic area in the country supposes a risk of the spread of the CSFV infection to the free zones, given this risk, the third study evaluated the sensitivity of active and passive surveillance in farms and slaughterhouses to detect infected farms in case the disease spread in two areas: one recognized as free (Zone 1) and another that at that time was in a process of eradication with suspension of vaccination (Zone 2). Scenario trees and stochastic models were used to describe the structure of surveillance and to determine the likelihood of detection of infected farms. The sensitivity of the system to detect the presence of a single infected farm in Zone 1 was 31.4% (95% CI: 7.2-54.1) and in Zone 2 it was 27.8% (95% CI: 6.4-55.1); in case of 5 farms were infected, the sensitivity was 85.2% (95% CI: 67.3-93.7) and 82.5% (95% CI: 62-92.9) respectively. Passive surveillance on farms presented higher sensitivity for the detection of an infected farm in both areas (22.8% in Zone 1 and 22.5% in Zone 2) compared to the other components. The probability of detection was higher in family farms/backyards compared to commercial ones. Passive surveillance in slaughterhouses had a sensitivity of 5.3% and 4.5% for the detection of a farm in Zones 1

and 2 respectively. Active surveillance on farms presented an overall sensitivity between 2.2% and 4.5%. One of the reasons why passive surveillance is more sensitive is the frequent monitoring by producers and veterinarians that is performed on a significant portion of premises. However, the report by producers depends on their awareness on the disease, the recognition of the clinical signs, their confidence in the veterinarian or contact personnel and their perception on the transparency in the reporting process. Therefore, it is important to strengthen factors that affect the sensitivity of the system, such as the ability of producers and veterinarians in the detection of clinical signs and educate them on the importance of the early report.

PUBLICACIONES

Los estudios presentados en esta tesis se han publicado en revistas científicas internacionales:

Estudio I: Descriptive epidemiology of classical swine fever outbreaks in the period 2013-2018 in Colombia

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Estudio III: Evaluation of the sensitivity of the classical swine fever surveillance system in two free zones in Colombia

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JUSTIFICACION

La peste porcina clásica (PPC) es considerada la enfermedad más importante en los cerdos domésticos y salvajes a nivel mundial (Blome et al, 2017; ML Penrith et al 2010;) siendo una de las enfermedades que cuenta con un reconocimiento de estatus sanitario oficial por parte de la Organización Mundial de Sanidad Animal (OIE). Actualmente varios países de Europa y América son reconocidos total o parcialmente libres; sin embargo, en otros la enfermedad se considera endémica o con enfermedad limitada a ciertas zonas. Los países americanos que están reconocidos como libres son: Argentina, Canadá, Chile, Costa Rica, Estados Unidos de América, México, Paraguay y Uruguay; así mismo zonas de Colombia y Brasil (OIE, 2021b)

El estatus sanitario de Colombia se divide en: 2 zonas reconocidas libres por la OIE, dos zonas auto declaradas libres por el ICA y zonas control o con vacunación donde se presentan focos. Esta zonificación con diversos estatus sanitarios dentro del programa exige la continua mejora y fortalecimiento de las acciones de vigilancia y control que permitan una detección temprana de la infección por el virus de la peste porcina clásica (VPPC) y la aplicación inmediata de medidas que permitan su erradicación, minimizando el impacto de la enfermedad en la producción.

Después de 6 años de ausencia de la enfermedad, en 2013 hubo una reintroducción del virus en el Noreste de Colombia que ocasionó 9 focos en ese año, a partir de ese momento se inició una tendencia ascendente de presentación de brotes que alcanzó su pico máximo en 2015 con 63 focos, que luego disminuyo hasta los 2 brotes en 2020. En total en el periodo 2013-2020 se presentaron 156 brotes en el país principalmente en producciones de traspatio de los departamentos de la Costa Atlántica.

En relación al origen de los focos, la hipótesis más plausible es que la enfermedad había ingresado al país por el contrabando de cerdos infectados con VPPC procedentes de Venezuela favorecido por la permeabilidad de la frontera, la mala situación socio-económica en Venezuela y el estatus sanitario endémico de ese país; sin embargo, con el transcurrir del tiempo la enfermedad se disemino en algunos departamentos de la Costa Atlántica Colombiana, debido a la idiosincrasia de la zona, a los bajos controles en la movilización de animales, la presencia de cerdos libres en las Ciénagas, las precarias practicas sanitarias y de bioseguridad de las explotaciones de traspatio de esta zona.

El impacto económico de la PPC en la industria porcina, se debe a las consecuencias directas e indirectas por la presentación de focos de la enfermedad. En los Países Bajos se calculó que las consecuencias de los brotes de PPC en el periodo 1997-1998 fueron de US $2.3 billones, mientras que las pérdidas para los productores y la industria fueron de US $423 y US $596 millones respectivamente (Meuwissen et al, 1999). En Latinoamérica, durante el periodo de erradicación de PPC en Chile entre 1983-1997 las pérdidas directas por morbilidad y mortalidad se estimaron en US 2.5 millones. (Pinto, 2000). Mientras que en Colombia no se han estimado las pérdidas que han ocasionado para la industria y la administración los brotes ocurridos en los últimos años.

La presencia de una zona endémica en el país supone un riesgo importante de diseminación hacia las zonas libres. La vigilancia epidemiológica juega un rol crucial en la detección de la infección por PPC, dado que la identificación temprana del virus es esencial para contrarrestar el impacto de su introducción en las zonas libres. En Colombia el sistema de vigilancia epidemiológica pasiva y activa está basado en los reportes de sospechas y muestreos representativos con el fin de realizar una detección precoz de infecciones; sin embargo, en la zona endémica, existe subnotificación de casos, falta de información o conocimiento por parte de los profesionales o productores que conllevan a las demoras en el reporte de los casos y en la atención de las notificaciones, por lo cual es necesario realizar una evaluación del funcionamiento del sistema de vigilancia.

Por lo anterior es de gran utilidad analizar en profundidad las posibles fuentes de infección y las relaciones epidemiológicas entre los brotes de PPC en los departamentos afectados, así como evaluar el costo que han ocasionado dichos brotes tanto para los pequeños productores, como para la industria y para la administración. Adicionalmente es importante conocer la sensibilidad del sistema de vigilancia epidemiológica en la zona libre para la detección de granjas infectadas con VPPC, lo cual permitirá valorar las posibles deficiencias para mejorarlo o complementarlo. Todo lo anterior permitirá conocer factores críticos del comportamiento de la enfermedad en el país, que contribuirán al fortalecimiento de las estrategias sanitarias implementadas para la prevención y control de la enfermedad en el país.

1. INTRODUCCION

1.1 Pregunta de investigación

Teniendo en cuenta las necesidades planteadas previamente, surgieron varias preguntas de investigación que se buscan cubrir con el desarrollo de esta tesis tales como: ¿Cuales han sido los mecanismos que han determinado la epidemiologia y distribución de los brotes de peste porcina clásica en Colombia?; ¿Cuantas han sido las pérdidas directas e indirectas que ha ocasionado los brotes para la industria y las administraciones en el país? ¿Las medidas sanitarias implementadas han sido efectivas para el control y contención de la enfermedad?; ¿Ante el riesgo de dispersión del VPPC, cual es la sensibilidad del sistema de vigilancia epidemiológica para la detección de granjas infectadas en las zonas libres en Colombia?

1.2 Características del virus de la peste porcina clásica

El virus de la peste porcina clásica (VPPC) pertenece al género de *Pestivirus* dentro de la familia *Flaviviridae*, junto con los virus de la diarrea vírica bovina 1 y 2 (VDVB-1, VDVB-2), el virus de la enfermedad de las fronteras (VEF) en ovejas (Blome, Staubach, et al., 2017; Edwards et al., 2000), y un número creciente de pestivirus no clasificados llamados atípicos derivados de varias especies que van desde los pestivirus pronghorn antílope, Bungowannah, jirafa, Hobi-like, Aydin-like, rata, virus ovino Tunecino hasta el pestivirus atípico porcino. (Riedel et al., 2021; Schweizer et al., 2014; Smith, D. B. et al., 2017; Wang et al., 2020).

El VPPC es un virus de ARN monocatenario y de sentido positivo de aproximadamente 12.300 nucleótidos de longitud.(Paton et al., 2000). El ORF codifica una poliproteína de aproximadamente 3900 aminoácidos que es co- y postraduccionalmente procesada por proteasas virales y celulares en once proteínas virales. La proteína del Núcleo (C) y las 3 glicoproteínas de la envoltura Erns, E1 y E2 constituyen la estructura vírica, además también se codifican siete proteínas no estructurales (Npro, p7, NS2, NS3, NS4A, NS4B, NS5A y NS5B).(Beer et al., 2015; Elbers, K. et al., 1996; Lamp et al., 2013).

1.2.1 Supervivencia e inactivación del VPPC

La supervivencia del VPPC en condiciones ambientales depende principalmente de la temperatura y del medio donde se encuentre. La durabilidad del virus se afecta por condiciones como la humedad, pH, presencia de materia orgánica y exposición a químicos (Edwards, 2000). Generalmente el tiempo de supervivencia es mayor en condiciones frías, húmedas y ricas en proteínas (Kramera et al., 2017). En haces y orina, el tiempo promedio de sobrevida del virus están entre 2 y 4 días a 5°C, y entre 1 y 3 horas 30°C.(Weesendorp et al., 2008); sin embargo, en estiércol en condiciones anaeróbicas, la supervivencia es corta (≤ 1 hora a 55°C).(Bøtner et al., 2012). En condiciones de laboratorio se puede inactivar el virus a 60°C por al menos 3 minutos. (Turner et al., 2000). Además, el VPPC es relativamente estable a un pH entre 5-10, donde la vida media del virus a un pH 3 es 10 veces más baja a 21°C bajos en lugar de 4°C (Depner, K. et al., 1992). El VPPC también puede sobrevivir hasta por 4.5 años en carne congelada a -70°C y de meses a años en productos cárnicos, (Farez et al., 1997); en los procesos de curado y maduración un factor crítico es el tiempo de duración y la temperatura de almacenamiento de los productos.(Edwards, 2000). La OIE recomienda un tratamiento térmico para carnes donde la temperatura interna alcance por lo menos 70°C, para carnes con fermentación natural y maduradas un tratamiento con aw ≤0.93 o pH ≤6 y para carnes secas o curadas con sal estilo italiano o español un periodo de 126 a 313 días, mientras que para la inactivación del VPPC en desperdicios, se recomienda 90°C por al menos 60 minutos ó 121°C mínimo por 10 minutos a una presión absoluta de 3 bares (OIE, 2021c).

1.3 Epidemiologia y transmisión

1.3.1 Transmisión

Las especies de la familia *suidae* son susceptibles al VPPC, especialmente los cerdos domésticos (*Sus scrofa domesticus*) y los jabalís salvajes (*Sus scrofa scrofa*). (Blacksell et al., 2006; Depner, K. R. et al., 1995). El virus puede transmitirse de forma horizontal y vertical. La transmisión horizontal ocurre por contacto directo entre cerdos infectados y susceptibles. (Blome, Moß, et al., 2017). La tasa básica de reproducción (R0) del VPPC por transmisión directa se ha estimado en cerdos destetados entre 81,3 y 100, en cerdos finalizados al R0 es 13,7 o 15,5, y en hembras de cría la R0 es 13.(Dewulf et al., 2001; Laevens et al., 1998, 1999); adicionalmente al R0 de transmisión entre corrales es de 7,77 y 3,39 en cerdos destetados y cerdos finalizados respectivamente (Klinkenberg et al., 2002).

El contacto indirecto por transmisión mecánica por personas, equipos, desperdicios de alimentación, comercio de animales y productos, camiones de transporte, estiércol y otros animales juegan un rol importante. (Ribbens et al., 2004). El contacto entre cerdos ferales y domésticos también es un factor importante para la transmisión del VPPC. Las explotaciones vecinas localizadas dentro de un radio de 500 m de granjas infectadas tienen un alto riesgo de infección, y el virus se disemina fácilmente a granjas localizadas en áreas con alta densidad de animales. (Fritzemeier et al., 2000; Staubach et al., 1997). La transmisión vertical de cerdas gestantes a los fetos es posible en todos los estadios de la gestación. La infección transplacentaria del feto depende del tiempo de gestación y la virulencia de la cepa. La infección de las cerdas entre el día 50-70 de gestación puede llevar al nacimiento de lechones virémicos persistentemente infectados (Moennig et al., 2003). También se puede presentar transmisión por semen de cerdos infectados.(Floegel et al., 2000).

1.3.2 Signos clínicos

La PPC tiene distintas formas de presentación que puede ir desde aguda o letal a la crónica de curso persistente, la cual requiere infección durante la gestación (Moennig et al., 2003). El periodo de incubación es aproximadamente de 10 días, de manera que en condiciones de campo los síntomas pueden evidenciarse en una explotación a las 2-4 semanas después de la introducción del virus. (Laevens et al., 1999). El progreso de la infección puede variar considerablemente, dependiendo de la virulencia de la cepa, respuesta del hospedador, edad, estado inmune e infecciones secundarias. En los animales reproductores de mayor edad, el curso de la infección a menudo es leve o subclínico. (Moennig et al., 2003; Petrov et al., 2014a). En cerdos jóvenes infectados con cepas de moderada virulencia, la fase aguda se caracteriza por signos clínicos inespecíficos o atípicos como fiebre alta, anorexia, síntomas gastrointestinales, decaimiento general y conjuntivitis. (Blome, Staubach, et al., 2017; Petrov et al., 2014a). Alrededor de las 2 a 4 semanas pueden ocurrir signos neurológicos como incoordinación, paresia, parálisis y convulsiones, al mismo tiempo que pueden ocurrir hemorragias cutáneas y cianosis en orejas, labios y abdomen ventral que se conocen como los signos típicos de la PPC. En el curso agudo letal, la muerte ocurre usualmente a las 2-4 semanas después de la infección con VPPC. La mortalidad puede alcanzar el 100% hasta los 30 días dependiendo de la edad del animal y la virulencia de la cepa. (Floegel-Niesmann et al., 2003, 2009).

El curso crónico de la enfermedad siempre es fatal y se desarrolla cuando los cerdos no pueden montar una respuesta inmune eficiente contra la infección. Los signos clínicos generalmente son inespecíficos tales como fiebre intermitente, depresión, emaciación y dermatitis difusa. Se ha descrito que los animales pueden sobrevivir aproximadamente hasta 4 meses antes de morir, en donde están eliminando altas cantidades de virus. (Blome, Staubach, et al., 2017; Moennig et al., 2003; Postel et al., 2018). En la enfermedad crónica, se pueden producir infecciones secundarias que complican el estado del animal, enmascarando la infección original con VPPC. Por lo tanto, al igual que en el curso agudo se deben considerar otras enfermedades como diagnostico diferencial.

La aparición tardía de PPC es una consecuencia de la infección intrauterina o postnatal muy temprana, ya que al igual que otros pestivirus, el VPPC puede atravesar la placenta en todos los estados de la gestación, también es una consecuencia típica de una infección con cepas de moderada a baja virulencia. El tiempo de la gestación y la virulencia del virus son factores cruciales en el desarrollo de la infección. La infección durante estadio temprano de la gestación puede resultar en abortos, mortinatos, momificaciones y malformaciones. (Dewulf et al., 2001; Moennig et al., 2003); sin embargo, la infección intrauterina entre los días 50 a 70 de gestación y de lechones al poco tiempo de nacidos puede llevar a animales con infección de forma persistente que aparentemente son sanos o tienen un crecimiento retardado. (Dahle et al., 1992; Muñoz-González et al., 2015). Estos animales al eliminar constantemente el virus se convierten en reservorios que puede propagar y mantener la infección dentro de las poblaciones de cerdos y tienen una gran importancia, porque pueden establecer una situación de enfermedad endémica, sin inducir signos clínicos graves que permitan una fácil detección y eliminación. (Postel et al., 2018; Van Oirschot, 1977)

1.4 Situación sanitaria mundial y Latinoamérica de la PPC

1.4.1 Distribución geográfica del VPPC

El VPPC tiene una alta variabilidad (Paton et al., 2000; Postel et al., 2012) y se han identificado 3 genotipos principales que contienen de 3 a 4 subgenotipos. (Beer et al., 2015; Lowings et al., 1996). La distribución de los genotipos muestra un patrón geográfico diferente, los aislados del grupo 3 han ocurrido principalmente en Asia, los aislados europeos de la década de los 90' y años posteriores corresponden principalmente a los subgrupos del genotipo 2 (2.1,2.2 o 2.3), el grupo 1 incluyen aislados históricos de Europa y de Estados Unidos y las cepas vacunales (Beer et al., 2015; Blome, Staubach, et al., 2017; Postel, Moennig, et al., 2013). Hay poca información de África y Oriente medio; sin embargo en brotes de PPC en 2005 en Sudáfrica y en 2009 en Israel se identificaron aislados del subgenotipo 2.1 (David et al., 2011; Sandvik et al., 2005), mientras que en India se ha demostrado la circulación de los subgenotipos 1.1,2.1 y 2.2 (Khatoon et al., 2017; Singh et al., 2017). China tiene una situación de alta variabilidad de aislados de PPC, en donde antes de 2008 existían los 4 subgenotipos 1.1,2.1,2.2 y 2.3, siendo el 2.1 más predominante y seguido de los 1.1, 2.2 y 2.3 que estaban geográficamente dispersos. Bajo la presión de la vacunación con cepa C, la mayoría de subgenotipos disminuyeron a excepción del 2.1que es más distante filogenéticamente de la vacuna. (Zhou, 2019).

Los aislados del continente Americano generalmente han pertenecido al grupo 1, de los cuales las cepas aisladas en Argentina, Brasil, Colombia y México pertenecen al subgenotipo 1.1, mientras que las cepas de Honduras y Guatemala corresponden al subgrupo 1.3 (Pereda et al., 2005; Sabogal et al., 2006), y los aislados de Cuba pertenecen al nuevo subgenotipo 1.4. (Postel, Schmeiser, et al., 2013). Recientemente se han identificado otros aislados en Brasil, Perú y Ecuador con diferencias genéticas que sugieren la existencia de los nuevos subgenotipos 1.5 y 1.6 (Araínga et al., 2010; Silva et al., 2017). En Colombia se ha descrito también el subgenotipo 2.2 (Garrido Haro et al., 2018). Se ha identificado, que la variabilidad genética no resulta en verdaderos serotipos y no afecta la eficacia de la vacuna, en general, el VPPC es altamente estable pese a ser un virus ARN (Greiser-Wilke et al., 2006). Otras investigaciones sobre el rol de la composición de las quasiespecies no llevaron a establecer una correlación entre la variabilidad y la virulencia, además tampoco se encontraron predictores de los diferentes cursos de enfermedad (Jenckel et al., 2017; Töpfer et al., 2013).

1.4.2 Situación sanitaria de la PPC

Actualmente la OIE reconoce como países libres de la enfermedad a Europea excepto Rumania y otros países de Europa Oriental; Kazakhstan en Asia; Australia, Nueva Caledonia y Nueva Zelanda en Oceanía. En las Américas tienen este reconocimiento: Argentina, Canadá, Chile, Costa Rica, Estados Unidos, México, Paraguay, Uruguay y algunas áreas de Brasil, Colombia y Ecuador (Figura 1). (OIE, 2021b). Entre enero de 2019 y junio de 2021, se han presentado 3.523 nuevos brotes a nivel mundial, que han causado la muerte de 4.757 suidos (domésticos y jabalíes), donde Asia y Latinoamérica son la principales regiones afectadas con 3.322 y 183 brotes, que afectaron a 11.645 y 8.233 animales y provocaron 2.232 y 2.517 muertos respectivamente. Los países que han tenido más brotes en el periodo de 2019 a junio de 2021 son: Japón (3.117), Indonesia (133), Vietnam (59), Brasil y Perú (44 C/U), Cuba (43), Colombia y Ecuador (20 C/U) (OIE, 2021a).

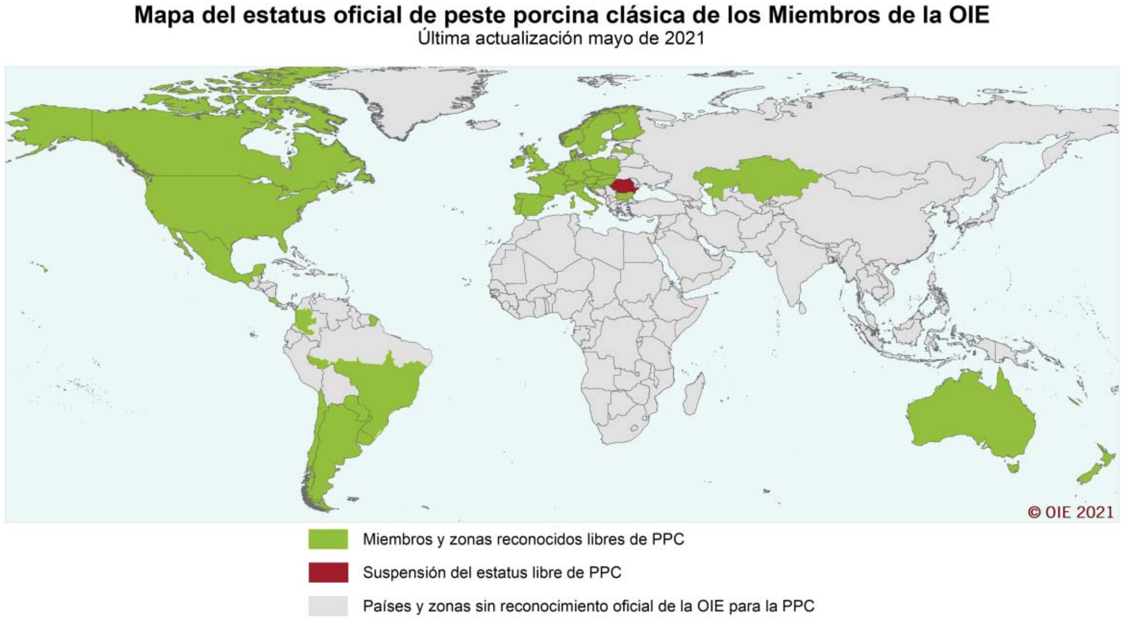


Figura 1. Estatus sanitario oficial de la PPC. Fuente: (OIE, 2021b).

En Colombia entre 2013 y 2020 se presentaron 156 focos (Figura 2), principalmente en la región de la Costa Atlántica (norte del país), con un promedio anual de 20 brotes, siendo el 2015 el año de mayor ocurrencia.

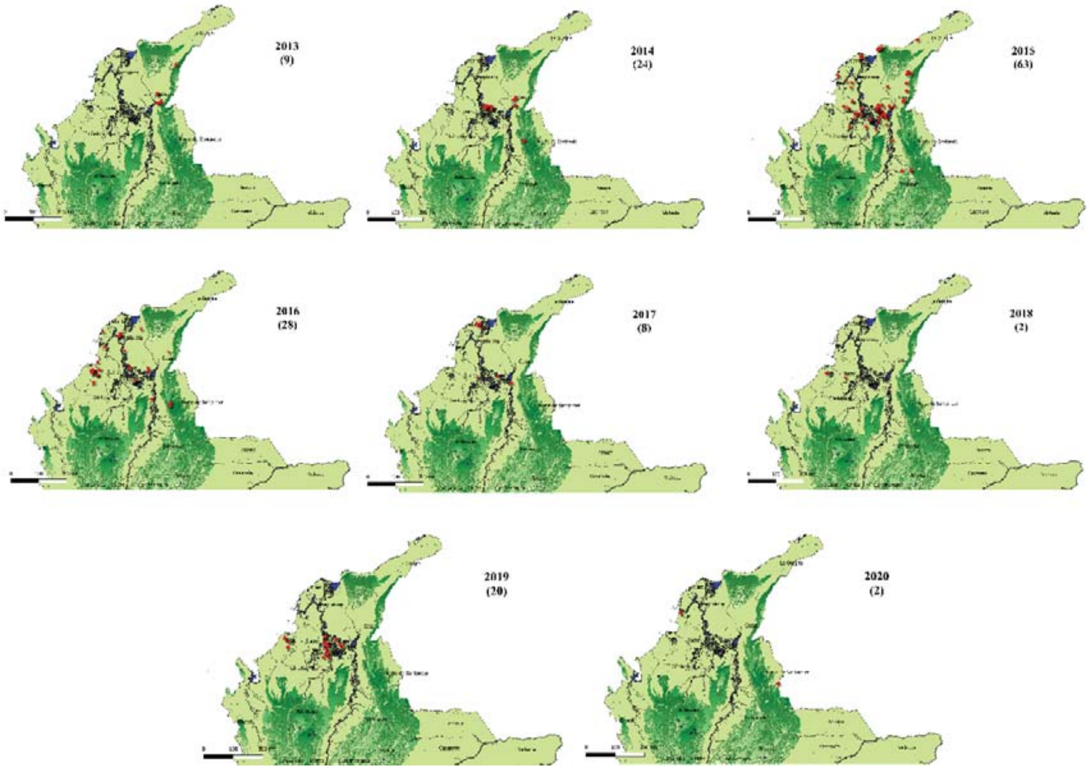


Figura 2. Distribución anual de los focos de PPC presentados entre 2013 y 2020.

1.5 Estrategias de prevención y control

Actualmente no existe un tratamiento para la enfermedad, por lo cual las estrategias sanitarias en las zonas endémicas están basadas en vacunación, control de movimientos, vigilancia epidemiológica, diagnóstico de laboratorio y bioseguridad en predios; mientras que en los países o zonas libres están basadas en la detección precoz y el sacrificio sanitario junto con las demás medidas descritas, a excepción de la vacunación (OIE, 2020a).

1.5.1 Vacunación

Las vacunas vivas atenuadas han sido altamente eficaces y seguras en el control de la PPC, la mayoría de estas derivan de la cepa china, atenuadas por varios pases en animales o en cultivos celulares. (Blome, Moß, et al., 2017; Van Oirschot, 2003). Estas vacunas se han utilizado durante décadas en el control de la enfermedad y se han implementado como obligatorias en programas de control a nivel mundial (Greiser-Wilke et al., 2004). La inmunidad protectora generada por estas vacunas es fuerte y duradera, donde puede llegar a durar hasta 10 meses y en algunos casos de por vida (Ferrari, 1992; Kaden et al., 2001; QIU et al., 2006; Van Oirschot, 2003). Adicionalmente, este tipo de vacunas también se han adaptado para vacunación oral con carnaza en jabalís, obteniendo buenos resultados en control de brotes cuando la vacunación está extendida y tiene una duración suficiente; sin embargo tiene limitaciones en la detección de animales positivos en el monitoreo de brotes, dado que estas vacunas no permiten diferenciar los infectados de los vacunados (Kaden et al., 2001; Rossi et al., 2015). Otra limitación es el consumo de mayor cantidad de carnazas en adultos por la estructura jerárquica que poseen las familias de jabalís que se puede resolver con barreras para que solo ingresen los cerdos jóvenes (Moennig, 2015). La vacunación oral se ha mostrado también como una herramienta complementaria que puede adaptarse a las circunstancias locales en granjas de traspatio (Milicevic et al., 2013; Monger et al., 2016; Porntrakulpipat et al., 2016).

También se han desarrollado vacunas marcadas. Las de primera generación a partir de la subunidad E2 presentan limitaciones de eficacia, aplicación y producción respecto a las vivas atenuadas (de Smit et al., 2000; Van Oirschot, 2003; Ziegler U, 2002), para superar estas limitantes se han desarrollado nuevas generaciones de vacunas marcadoras. En condiciones de campo las vacunas marcadoras deben ir acompañadas de un potente sistema de prueba, que ha sido una de las debilidades, ya que la estrategia de vacunación debe estar bien establecida y con un flujo de diagnóstico adecuado. (Blome, Moß, et al., 2017). En los últimos años se ha producido un importante desarrollo de vacunas que incluyen las recombinantes, recombinantes inactivadas o de subunidades, vacunas de vectores y vacunas de ADN/ARN, donde las vacunas de deleción especialmente atenuadas o las construcciones quiméricas han mostrado potencial.

Adicionalmente, para que la vacunación en campo sea adecuada y evitar fallas en el proceso, se deben tener en cuenta varios factores críticos que afectan directamente a la vacunación como lo son: tiempo adecuado de la campaña, mantenimiento de la cadena de frio (almacenamiento y transporte), interferencia con anticuerpos maternales, complicaciones con otros patógenos y el cubrimiento de área rurales o distantes, etc. (Blome, Moß, et al., 2017; Luo et al., 2014; Suradhat et al., 2007a).

1.5.2 Vigilancia epidemiológica

Debido a la variabilidad de formas de presentación clínica (desde aguda a crónica con animales persistentemente infectados) y de signos clínicos que muchas veces son inespecíficos y pueden confundirse con otras enfermedades, la vigilancia de la enfermedad debe incluir varias estrategias que permitan la detección temprana de animales infectados a través de toda la cadena producción, distribución y transformación, además debe cubrir las poblaciones de cerdos domésticos y silvestres que existan en el país (OIE, 2021c).

Las principales estrategias son: *Vigilancia Clínica:* es la más importante para la detección de animales infectados por VPPC, donde se deben evaluar los casos que presentan signos clínicos y lesiones acompañados de alta morbilidad o mortalidad. Sin embargo, debido a la presencia de cepas de moderada o baja virulencia es posible que los adultos no manifiesten signos clínicos, por lo cual se debe aplicar especial atención a los animales jóvenes y complementar con vigilancia serológica y virológica.

Vigilancia Virológica: se debe realizar en poblaciones de riesgo, investigación de casos sospechosos, seguimiento de resultados serológicos positivos y para investigar aumento de mortalidades. Los métodos de detección molecular se pueden aplicar para la detección del virus a gran escala y en grupos de alto riesgo facilitan la detección temprana.

Vigilancia serológica: Este tipo de vigilancia tiene por finalidad detectar anticuerpos contra el VPPC; los resultados positivos pueden indicar: infección natural, vacunación, presencia de anticuerpos maternos, reacciones cruzadas con otros pestivirus y resultados no específicos. Se debe descartar la presencia de anticuerpos de otros pestivirus como diarrea viral bovina y enfermedad de la frontera y también se debe considerar que pueden existir animales jóvenes infectados de forma crónica con títulos de anticuerpos indetectables o fluctuantes que no son detectados por serología. Adicionalmente en las zonas donde la vacunación se ha interrumpido recientemente, los anticuerpos maternales de los animales jóvenes pueden durar hasta las 8-10 semanas de edad y en algunos casos hasta los 4 meses (OIE, 2021c).

En los sistemas de vigilancia se deben considerar factores que afectan el reporte de brotes como lo son: falta de conocimiento de los signos clínicos de la enfermedad que se ha evidenciado en áreas donde la enfermedad no ocurre por más de 10 años, opiniones negativas sobre las medidas de control e insatisfacción con el proceso de reporte, falta de confianza en las autoridades, incertidumbre y falta de transparencia en los procedimientos de reporte (Elbers, A. R. et al., 2010). Adicionalmente, en otros estudios se ha observado que la especialización de los veterinarios y la mejora del conocimiento de los signos clínicos junto con examen patológico y virológico, son métodos efectivos para la identificación temprana de brotes de PPC (Crauwels et al., 1999; Engel et al., 2005a)

1.5.3 Otras medidas sanitarias:

La OIE recomienda las siguientes estrategias sanitarias profilácticas: comunicación efectiva entre autoridades, veterinarios y productores, efectivo sistema de reporte, controles estrictos de importación de cerdos vivos y sus productos, cuarentena de animales, esterilización de desperdicios de alimentos o su prohibición, eficiente control de plantas de transformación de desechos, vigilancia serológica de animales de reproducción, efectivo sistema de registro e identificación. En relación a la respuesta ante los brotes recomienda: sacrificio de todos los cerdos en granjas afectadas, disposición segura de carcasas, camas y otros desechos, desinfección profunda, con control/prohibición de movimientos en las zonas infectadas, investigación epidemiológica detallada con rastreo de posibles fuentes de origen y propagación de la infección y vigilancia de la zona infectada y área circundante (OIE, 2020a).

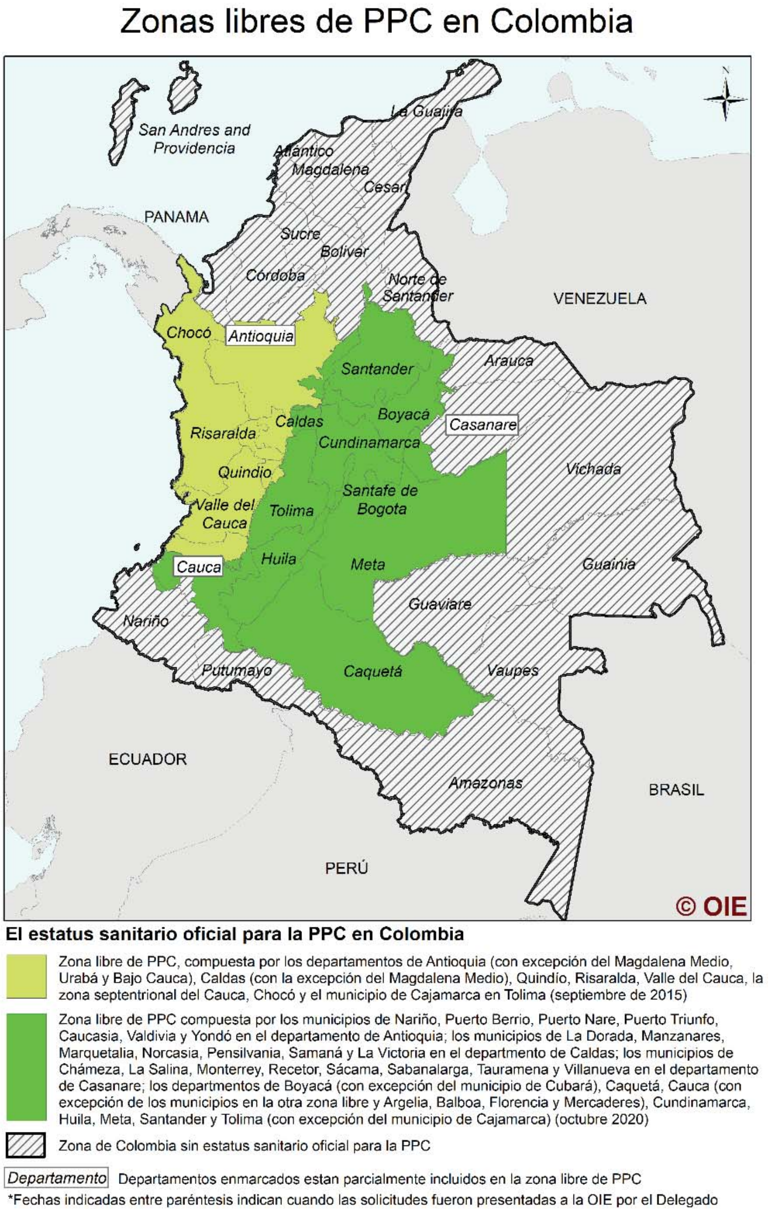
1.6 Programa de control de Colombia

En Colombia la erradicación de la Peste Porcina Clásica (PPC) se declaró de interés social nacional a través de la Ley 623 del 2000, el decreto 930 del 2002 y la resolución ICA 2129 del 2002, en donde se establecen las medidas de prevención, control y erradicación de la enfermedad en el país. A partir de ese momento se direccionaron las acciones sanitarias entre el servicio sanitario oficial (Instituto Colombiano Agropecuario - ICA) y la Asociación Colombiana de Porcicultores – Porkcolombia / Fondo Nacional de la Porcicultura para controlar y erradicar la enfermedad en el país a través de un programa de cogestión entre las dos entidades, en donde el ICA es responsable de las acciones de vigilancia epidemiológica, diagnóstico y control de movimientos y Porkcolombia de la vacunación e identificación de cerdos en el país. El programa de control se fundamenta en la vigilancia epidemiológica, vacunación y control de movimientos.

Entre 2009 y 2010 se presentaron los primeros avances del programa, con el autoreconocimiento de las primeras dos Zonas Libres de PPC en el país; la primera zona fue reconocida en 2009 y comprende los departamentos de Amazonas, San Andrés y Providencia y los municipios de Vigía del Fuerte y Murindó en Antioquia y los municipios de Acandí, Bojayá, Bahía Solano, El Carmen del Darién, Unguía, Riosucio y Juradó del Choco); mientras que la segunda fue autodeclarada al año siguiente y está conformada por los departamentos de Vichada, Guainía, Guaviare, Vaupés y el municipio de Puerto Concordia - Meta.

En el 2011 se reconoció la tercera Zona Libre; sin embargo, no fue reconocida por OIE hasta el 2015, la cual es la principal zona de producción porcícola y concentra el 70% de la producción porcícola tecnificada del país. Esta zona está compuesta por los departamentos Antioquia (Con excepción del Magdalena Medio, Urabá y Bajo Cauca Antioqueños), Zona centro-sur del Chocó, Valle del Cauca, Norte del Cauca (municipios de Buenos Aires, Caloto, Corinto, Caldoso, Jambaló, López, Miranda, Morales, Padilla, Puerto Tejada, Santander de Quilichao, Suarez, Toribio y Villa Rica.), Caldas (con excepción del Magdalena Medio Caldense), Quindío, Risaralda y el municipio de Cajamarca en el departamento del Tolima. Figura 3.

Las zonas libres cuentan con restricciones a la movilización y comercialización de cerdos desde otras zonas, lo cual se realiza a través de puestos de control ubicados en puntos estratégicos alrededor de las zonas, adicionalmente se realizan muestreos serológicos anuales para la detección de posibles casos de infección del VPPC.



El estatus sanitario oficial para la PPC en Colombia

🟩 Zona libre de PPC, compuesta por los departamentos de Antioquia (con excepción del Magdalena Medio, Urabá y Bajo Cauca), Caldas (con la excepción del Magdalena Medio), Quindío, Risaralda, Valle del Cauca, la zona septentrional del Cauca, Chocó y el municipio de Cajamarca en Tolima (septiembre de 2015)

🟩 Zona libre de PPC compuesta por los municipios de Nariño, Puerto Berrio, Puerto Nare, Puerto Triunfo, Caucasia, Valdivia y Yondó en el departamento de Antioquia; los municipios de La Dorada, Manzanares, Marquetalia, Norcasia, Pensilvania, Samaná y La Victoria en el departmento de Caldas; los municipios de Chámeza, La Salina, Monterrey, Recetor, Sácama, Sabanalarga, Tauramena y Villanueva en el departamento de Casanare; los departmentos de Boyacá (con excepción del municipio de Cubará), Caquetá, Cauca (con excepción de los municipios en la otra zona libre y Argelia, Balboa, Florencia y Mercaderes), Cundinamarca, Huila, Meta, Santander y Tolima (con excepción del municipio de Cajamarca) (octubre 2020)

▨ Zona de Colombia sin estatus sanitario oficial para la PPC

Departamento Departamentos enmarcados estan parcialmente incluidos en la zona libre de PPC

*Fechas indicadas entre paréntesis indican cuando las solicitudes fueron presentadas a la OIE por el Delegado

Figura 3. Zonas libres de PPC en Colombia. Fuente: (OIE, 2021b).

Posteriormente en mayo de 2013, con miras a declarar otra zona libre se interrumpió la vacunación contra PPC en la región del norte (Costa Atlántica) y centro del país, conformada por los departamentos de Atlántico, Bolívar, Caquetá, Cesar; Córdoba, Cundinamarca, Huila, Tolima, Magdalena, Meta, Santander, Sucre, Boyacá, Cauca; la región del Magdalena Medio Caldense, Bajo Cauca, Urabá y Magdalena Medio Antioqueño y varios municipios de los departamentos de Casanare; Cesar, La Guajira y Norte de Santander. Sin embargo, debido a la presentación de focos de PPC entre 2013 y 2015 en los departamentos de La Guajira, Cesar, Bolívar, Magdalena y Norte de Santander, se reinició la vacunación de forma indefinida en los departamentos de la Costa Atlántica, Norte de Santander y las Zonas de Urabá y Bajo Cauca Antioqueño.

En 2015 se detectaron 3 focos en el departamento de Santander por lo que se decidió retomar la vacunación en los departamentos del centro del país, lo cual se llevó a cabo hasta el 2016, cuando fue interrumpida nuevamente la vacunación. Esta zona está compuesta por los departamentos Santander, Boyacá, Meta, Cundinamarca, Huila, Tolima, Cauca, Caquetá, así como las zonas del Bajo Cauca, Magdalena Medio Antioqueño y Magdalena Medio Caldense y ha sido reconocida por OIE como libre en mayo de 2021 (Figura 3).

La zona control con vacunación y presencia ocasional de brotes, está compuesta por departamentos de la Costa Atlántica y fronterizos con Venezuela y Ecuador. Dentro de las estrategias que se aplican está la vacunación gratuita para productores a través de un equipo de 300-350 vacunadores anuales en promedio y con cobertura vacunales superiores al 90% de los animales censados.

En la actualidad el estatus sanitario de Colombia con respecto a la enfermedad se encuentra zonificado en: Zonas Libres sin vacunación (2 autoreconocidas y 2 con reconocimiento de la OIE) y una zona control o con vacunación.

2. HIPOTESIS Y OBJETIVOS

2.1 Hipótesis

La PPC es actualmente endémica en algunas zonas de Colombia, sin que se conozca el patrón epidemiológico de los brotes y el impacto económico para la administración y la industria, por lo que supone un riesgo claro para las zonas libres de la infección. Por una parte, el coste de la enfermedad en Colombia es elevado, y por otra, la capacidad de detectar la infección en caso de aparición de un brote en granjas de las zonas libres es relativamente alta.

2.2 Objetivos

Objetivo general: Evaluar el comportamiento epidemiológico e impacto económico de los brotes de peste porcina clásica, así como el sistema de vigilancia en las zonas libres.

Objetivos secundarios:

1. Análisis y caracterización de los casos de PPC en Colombia en el periodo 2013-2018
2. Evaluar el impacto económico de los brotes de peste porcina clásica en Colombia.
3. Determinar la sensibilidad de la vigilancia epidemiológica en la detección de PPC en Zonas libres.

3. ESTUDIO I

Descriptive epidemiology of classical swine fever outbreaks in the period 2013-2018 in Colombia

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3.1 Abstract

Classical swine fever (CSF) is an infectious viral disease caused by an RNA virus belonging to the Pestivirus genus. A total of 134 outbreaks of CSF have occurred in the last seven years in the North of Colombia. The objective of this study was the characterization of the herds affected by CSF from 2013 to 2018. Most of the outbreaks (95%) occured in backyard piggeries. The principal causes of transmission of CSF were the introduction of infected pigs (38%), movements of people (37%) and unknown origin (13%). The epidemiological relationships with 15 affected farms explained 31 outbreaks. The overall attack and mortality rates were 39% and 32%, respectively. The main clinical signs were high fever (67%), incoordination of movements (54%), and prostration (52%). Seventy-three percent of the herds had not been vaccinated against CSF and 17% had been only partially vaccinated. A spatio-temporal analysis, using a Poisson regression model, revealed two clusters with high risk; the first and largest one from 2014 to 2016 had a relative risk (RR) of 13.4 and included part of the departments of Atlántico, Bolívar, Cesar, La Guajira, Norte de Santander, Magdalena and Sucre; and the second cluster (RR=9.6 in 2016) included municipalities in the north of the department of Cordoba.

3.2 Introduction

Classical swine fever (CSF) is an infectious viral disease caused by an enveloped RNA virus classified in the family *Flaviviridae*, genus *Pestivirus* (OIE, 2009; Ribbens et al., 2004). It is one of the most important diseases in pigs, with great impact on health and the swine industry (Blome, Staubach, et al., 2017; Penrith et al., 2011). Pigs and wild boar are the only natural reservoir. CSF virus (CSFV) can be transmitted both horizontally and vertically. The horizontal transmission occurs through direct contact between infected and susceptible pigs (Blome, Moß, et al., 2017). Additionally, indirect contact by mechanical transmission, by people, equipment, swill feeding, and (illegal) trade of animals and animal products, livestock trucks, slurry, other animals, plays an important role (Ribbens et al., 2004). The contact between feral and domestic pigs is also an important factor for the transmission of the virus. Neighboring premises located within a radius of 500 m of infected farms have a higher risk of infection, and the virus easily spreads on premises located in areas with a high density of pigs (Fritzemeier et al., 2000; Staubach et al., 1997).

In America, CSFV is present in Cuba, Dominican Republic, Ecuador, Haiti, Peru and in certain areas of Brazil and Colombia (OIE, 2009). Other countries, such as Argentina, Chile or Canada, among others, are recognized as free countries, as well as some areas of Brazil, Colombia and Ecuador (OIE, 2020b).

Colombia has a swine census of 5.5 million pigs distributed in 239,199 premises, 88.2% of them are backyard producers that reared 35.8% of the census. CSF was endemic in Colombia until the decade of 2000, when an eradication program reduced the disease to the limits of eradication in 2007. The strains of the outbreaks that occurred between 1998 and 2006 belonged to subgroups 1.1 and 2.2 (Mogollon et al., 2008; Sabogal et al., 2006).

CSF is a notifiable disease in Colombia, besides the compulsory notification by all producers and professionals of the swine sector, a fundamental component of the passive surveillance is a sentinel surveillance network made up of approximately 5,000 veterinarians and para-veterinarians distributed all over the country. These are specifically trained, and report suspected notifiable diseases. Active surveillance is performed only in free zones or in the process of eradication.

The control program is based on vaccination with a live attenuated-C strain vaccine, control of movements of pigs through a health certificate and checkpoints, and passive and active epidemiological surveillance. The program is developed and managed jointly between the official veterinary service (ICA) and the Colombian Pork Producers Association (Porkcolombia), where the ICA is responsible for the direction and development of measures of epidemiological surveillance, control and eradication of the disease, and Porkcolombia is responsible for the vaccination campaign and provides the vaccine. Vaccination is compulsory in endemic or at-risk areas, and the producers are responsible for the application of the vaccine in the commercial farms, while the backyard piggeries are vaccinated by Porkcolombia workers as a free service (ICA, 2002).

According to ICA contingency plan for CSF, diseased and contact animals in affected premises are sacrificed and disposed of safely, facilities are cleaned, disinfected, and remain without animals for 30 days after disposal of the last sick animal. Partial restocking with sentinel pigs for a 21-day period, is conducted before total repopulation. Protection and surveillance areas of 3 km and 7 km, respectively, around the outbreak are defined, where movements are restricted, and vaccination is carried out depending on the region. Finally, an epidemiological investigation to determine possible epidemiological relationships is undertaken.

Colombia has been divided according to disease status into different areas. Departments recognized as CSF free by the OIE (departments of Antioquia, Caldas, Quindio, Risaralda, Valle del Cauca, and the northern area of Cauca). The self-declared free areas (departments of Amazonas, San Andres de Providencia, Guainia, Guaviare, Vaupes, and Vichada). An area under eradication process without vaccination (departments in the south center of the country). A control zone with vaccination (departments of Atlantic Coast and departments of Arauca, Norte de Santander, Casanare, Nariño and Putumayo that are bordering Venezuela and Ecuador) (ICA, 2018).

The aim of the present study was the description and characterization of the 134 outbreaks of CSF that occurred in Colombia in the period 2013 – 2018, and the analysis of the temporospatial distribution of the cases, in order to identify the areas of greatest risk.

3.3 Materials and Methods

3.3.1 Country and area under study

Colombia is located in the northwestern region of South America on the equatorial line, with a land area of 1,141,748 km^2. The country is divided into 32 departments, which are grouped into six naturals regions: Amazon, Andean, Atlantic Coast, Insular, Orinoco, and Pacific.

The outbreaks appeared in the Atlantic Coast region, also known as Caribbean, which has an area of 132.288km^2 and it is located in the north of the country, bordering with the Caribbean Sea and with Venezuela. Some outbreaks appeared in Norte de Santander and Santander (from the Andean region), very close to the border with Atlantic Coast region and Venezuela.

The Atlantic Coast region, where 126 of the 134 outbreaks occurred, has a porcine census of 1,277,340 pigs (23.2% of Colombian pigs). In this region, there is a high proportion of backyard premises (99.8% of the farms, and 91% of the pig census) (Table 1). These farms are characterized by a small number of animals, low technology, low level of biosecurity, and their unregulated situation. In addition, pigs in marshy areas (swamps of Grande de Santa Marta, Zapatosa, Ciénaga Grande del Sinú, Ayapel, and the Magdalena River) are free ranging during the dry season, and some of them can become feral.

The departments of Norte de Santander and Santander have a census population of 160,947 pigs, of which 51.2% are backyard pigs. These departments are characterized for having more commercial premises with a medium biosecurity level.

Table 1. Census of pigs in the CSF affected departments of Colombia

Department	Number of commercial farms - 2018	Census pigs in commercial farms - 2018	Number of backyard premises – 2018	Census pigs in backyard premises - 2018	Proportion of backyard premises	Proportion of backyard pigs
Atlántico	125	85,725	5,213	87,328	97.7%	50.5%
Bolívar	6	5,556	14,505	123,614	100.0%	95.7%
Cesar	29	4,405	7,844	72,973	99.6%	94.3%
Córdoba	18	10,770	41,379	369,440	100.0%	97.2%
La Guajira	-	-	2,617	42,287	100.0%	100.0%
Magdalena	17	5,668	15,040	255,100	99.9%	97.8%
Sucre	64	6,493	28,810	207,981	99.8%	97.0%
Total Atlantic Coast	**259**	**118,617**	**115,408**	**1,158,723**	**99.8%**	**90.7%**
Norte Santander	8,676	65,228	4,961	19,170	36.4%	22.7%
Santander	41	13,364	3,129	63,185	98.7%	82.5%
Total others	**8,717**	**78,592**	**8,090**	**82,355**	**48.1%**	**51.2%**
Grand Total	**8,976**	**197,209**	**123,498**	**1,241,078**	**93.2%**	**86.3%**

Source: Census of pigs - National Livestock Census – 2018 - Epidemiological surveillance -ICA (ICA, 2019b)

3.3.2 Data gathering

All confirmed CSF outbreaks declared in the country between 2013 and 2018 were included in this study. The information of each outbreak was obtained by veterinarians of the official veterinary services (ICA) using two questionnaires: the first one was completed on the notification of the suspicion of the outbreak, and the other one during the follow-up of the outbreak. These questionnaires included the disease notification date, characteristics of the farm, vaccination, animals affected by groups, clinical signs and movements of animals and people. The veterinary officer that completed the questionnaire also asked about routes of disease introduction and epidemiological links between premises.

We performed a descriptive analysis of the different variables associated with the morbidity and mortality rates, clinical signs, the transmission mechanisms of the virus, and response to the outbreak. The most probable routes of CSF introduction and epidemiological links between premises were determined by taking into account the information in the questionnaires and records of swine movements. For the determination of the causes of introduction, in outbreaks where two or three causes were possible, the contribution of each one was divided by the number of causes, i.e. if the cause could be either animal movements or neighbors, both causes were scored 0.5. In the same way, in the case of three possible causes each of them was scored 0.3. If more than 3 causes were possible the most likely cause of infection was considered as unknown.

When the infection affected different backyard premises that shared environment and management practices, the small village was considered an epidemiological unit, and defined as a single outbreak.

Ethics Statement:

This study did not need any ethical approval, as it did not include samples or experiments on people. It only included data collected by Department of Animal Health veterinary officers during the epidemiological survey in the outbreaks. Data about identification of the premises and localization further than the municipality were not analyzed in order to avoid the association of any data with the premise where it was obtained.

3.3.3 Spatio-Temporal Analysis

A Poisson regression model (SaTScan version 9.6 program) was used to identify possible temporospatial clusters. The model takes into account the number of CSF outbreaks in relation to the number of pig premises by year at risk. The 134 outbreaks that occurred in the period between 1 January 2013 and 31 December 2018 were analyzed. The data were obtained from ICA (ICA, 2019b, 2019a). Only clusters with statistical significance ($p < 0.05$)

were reported, due to the excess of cases observed over the expected ones. The cartographic representations were made using the QGIS 3.4 program.

3.4 Results

3.4.1 Affected departments and premises

Between 2013 and 2018, 134 outbreaks of CSF affected the Northern part of Colombia, with almost half of them (63; 47%) occurring in 2015 (Table 2 and Fig 2). The most affected departments were Magdalena and Cesar. All the outbreaks occurred in departments of the Atlantic Coast region, except the 5 and 3 cases that occurred in Norte de Santander and Santander, respectively, belonging to the Andean region.

The affected departments are characterized by a high proportion of backyard units (93.2%), which are consequently the most affected (127 outbreaks, 94.8% of the pig units). One of the seven farms classified as commercial that became infected had 460 sows, the other were small premises with 4-34 sows or less than 22 fatteners.

Table 2. Distribution of CSF outbreaks in Colombia

Departaments	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**TOTAL**
Atlántico	-	-	3	4	5	-	12 (8.9%)
Bolívar	-	2	14	4	-	1	21 (15.6%)
Cesar	8	5	12	1	1	-	27 (20.1%)
Córdoba	-	-	-	11	-	1	12 (8.9%)
La Guajira	1	-	1	-	-	-	2 (1.5%)
Magdalena	-	15	20	5	1	-	41 (30.5%)
Norte Santander	-	2	-	3	-	-	5 (3.7%)
Santander	-	-	3	-	-	-	3 (2.2%)
Sucre	-	-	10	-	1	-	11 (8.2%)
GRAND TOTAL	**9 (6.7%)**	**24 (17.9%)**	**63 (47%)**	**28 (20.9%)**	**8 (5.9%)**	**2 (1.5%)**	**134**

Seventy two percent of the backyard's piggeries (91 premises) were located in urban and semi-rural areas, while 28% (35) were located less than 1 km far from bodies of water (swamps of the Colombian Atlantic Coast or Magdalena River).

3.4.2 Detection of CSF outbreaks and response times

Most of the outbreaks (84%) were detected by passive surveillance: 69 cases (51%) were notified to the Health Service by the farmers, 23 (17%) by the voluntary sentinel networks and 21 (16%) by third parties. Another 21 premises (16%) were detected by active surveillance due to epidemiological relationships with the outbreaks. The 113 outbreaks detected by passive surveillance were the result of 945 suspicions of CSF declared in the affected regions between 2013 and 2018.

The time elapsed between the identification of clinical signs by the producer and the official declaration of the outbreak was long, especially in the first years. During the 6 years, the median of this period was 29 days (minimum 7; maximum 92); and in the last two years (2017 -2018) it was reduced to 15 days (minimum 7; maximum 38).

The two critical points during the 6 years were, the time between the identification of clinical signs by the producer or sentinel and the notification to the official veterinary service (median of 11 days, range 0 to 72), and the period between the official veterinary inspection and the confirmation by the National Veterinary Diagnostic Laboratory (median of 15 days, with a range of 4-78). In the two last years it was reduced to 5 (1 to 28) and 7 days (4 to19), respectively. The period between the notification and official veterinary inspection was 1 day (range 0 to 4).

3.4.3 Routes of transmission of CSFV and epidemiological links

The most frequently cited routes of transmission of CSFV between the outbreaks were the introduction of infected pigs (cited in 83 outbreaks) and the movement of people (cited in 77 cases). In 17 premises (13%) the origin was unknown (Table 3). Other causes, such as grazing with feral pigs or livestock vehicles were also cited but only in cases where more than one cause was considered.

Table 3. Possible causes of the introduction of the CSFV into the epidemiological units according to questionnaires and records.

Transmission route	**Number of possible causes indicated in the questionnaire**			**Total / Weighted percentage***
	1	**2**	**3**	
Introduction pigs	23	52	8	(52) 39%
People	24	46	7	(49) 37%
Unknown	17			(17) 13%
Grazing (swamps)		17	8	(11) 8%
Livestock trucks		4	2	(2.7) 2%
Domestics animals	1			(1) 0.7%
Neighbourhood herds			2	(0.7) 0.5%
Swill feeding		1		(0.5) 0.4%

* The percentage was calculated attributing a weight of 1, 0,5 and 0,33 if 1, 2 or 3 causes were indicated respectively. e.g. for introducing pigs: (23 x 1 + 52 x 0.5 + 8 x 0.33) = 52

The index case appeared in the municipality of Urumita (Cesar) in June 2013, near the border with Venezuela. According to the epidemiological data, the most probable origin of this outbreak was an illegal introduction of infected pigs from Venezuela.

Epidemiological links were established only in 31 outbreaks (23%), which can be related to 15 affected premises that could be the origin of the infection. All these relationships were between premises of the same or neighbor municipalities.

3.4.4 Attack and mortality rates and clinical signs

The overall attack and mortality rates were 39% and 32%, respectively (Table 4). The highest proportion of sick pigs (48%) occurred in animals aged 2 - 6 months, with sows having a lower attack rate (21%). The differences between groups were significant ($p < 0.001$), except when comparing piglets younger than 6 months and adult males. The case-fatality rate in the whole population was 83%, with no differences between age groups.

Table 4. Morbidity and mortality rates due to CSF in the 134 outbreaks, classified by age and gender.

Category	# Animals	Diseased	Deaths	Vaccinated	% Attack rate	% Mortality	% Case-fatality
Weaning Pigs <2 months old	3,054	1,174	990	146	38	32	84
Fatteners, 2 -6 months old	2,721	1,300	1,076	404	48	40	83
Males >6 Months old	350	138	110	45	39	31	80
Sow >6 Months old	1,296	273	225	583	21	17	82
Total	**7,421**	**2,885**	**2,401**	**1,178**	**39**	**32**	**83**

High fever was the most frequent clinical sign and was observed in 90 premises (67%), with incoordination of movements and prostration being observed in 73 and 70 premises (54% and 52%, respectively). Other clinical signs frequently observed were cough (59 premises, 44%), diarrhea (50, 37%), tremors (45, 34%), and depression and weakness (45, 33%) (Fig 1).

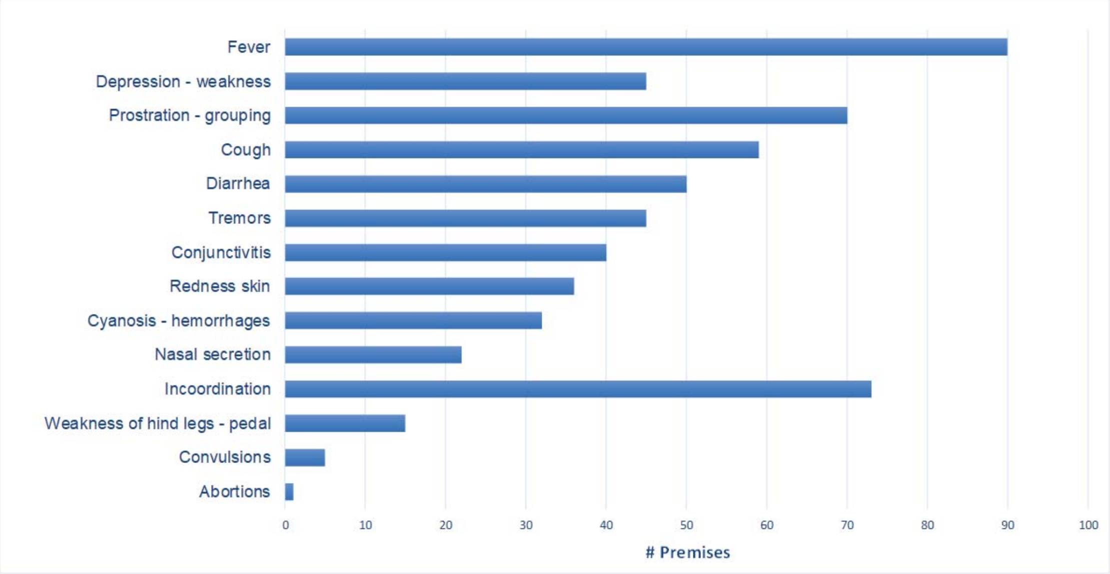

Fig 1. Frequency of clinical signs in the 134 outbreaks of CSF

3.4.5 Vaccination

Out of the 134 outbreaks, 98 (73%) had not been vaccinated against CSF, 23 (17%) had been only partially vaccinated, and the other 13 (10%) occurred in vaccinated premises. In 5 of these last premises, the vaccination was carried out 4 - 6 days before the presentation of the clinical signs. In one of the premises the vaccination was carried out the same day as the presentation of clinical signs, and in 2 premises it was carried out after the appearance of signs. Therefore, only 5 cases appeared in previously fully vaccinated herds. Three of the seven commercial farms that were affected had not been vaccinated and the other four farms were only partially vaccinated.

CSF vaccination was suspended in the departments of the Atlantic Coast region, Santander and Norte de Santander in June 2013 (just before the start of the first outbreak) as they were included in an eradication zone. When the outbreaks began in that year, 50,717 pigs from the Atlantic Coast located in affected municipalities or in a radius of 10 km around outbreaks were vaccinated. In September 2014, compulsory vaccination was set up again in the departments of the Atlantic Coast and in North Santander. A total of 980,752 pigs were vaccinated in the Atlantic Coast region and 53.547 in Norte de Santander in 2015, and in the consecutive years, about one and a half million animals were vaccinated yearly. In Santander, vaccination was reestablished in 2015 when the first CSF outbreaks occurred and was maintained until 2016 when it was stoped. In that period 108,775 pigs were vaccinated enabling a 90% of vaccination coverage (Porkcolombia/FNP, 2018).

3.4.6 Spatio-Temporal Analysis

The spatiotemporal analysis detected two statistically significant ($p < 0.05$) clusters (or zones of greater risk). The first one with a radius of 154.5 km, included part of the departments of Atlántico, Bolívar, Cesar, La Guajira, Norte de Santander, Magdalena and Sucre, with 5.6 outbreaks more than expected, and with a relative risk (RR) of 13.4, for the period between 2014 and 2016. The second cluster had a radius of 14.2 km and grouped municipalities from the north of the department of Córdoba. The RR for the year 2016 was 9.6 due to the detection of 9.02 cases more than expected (Fig 2).

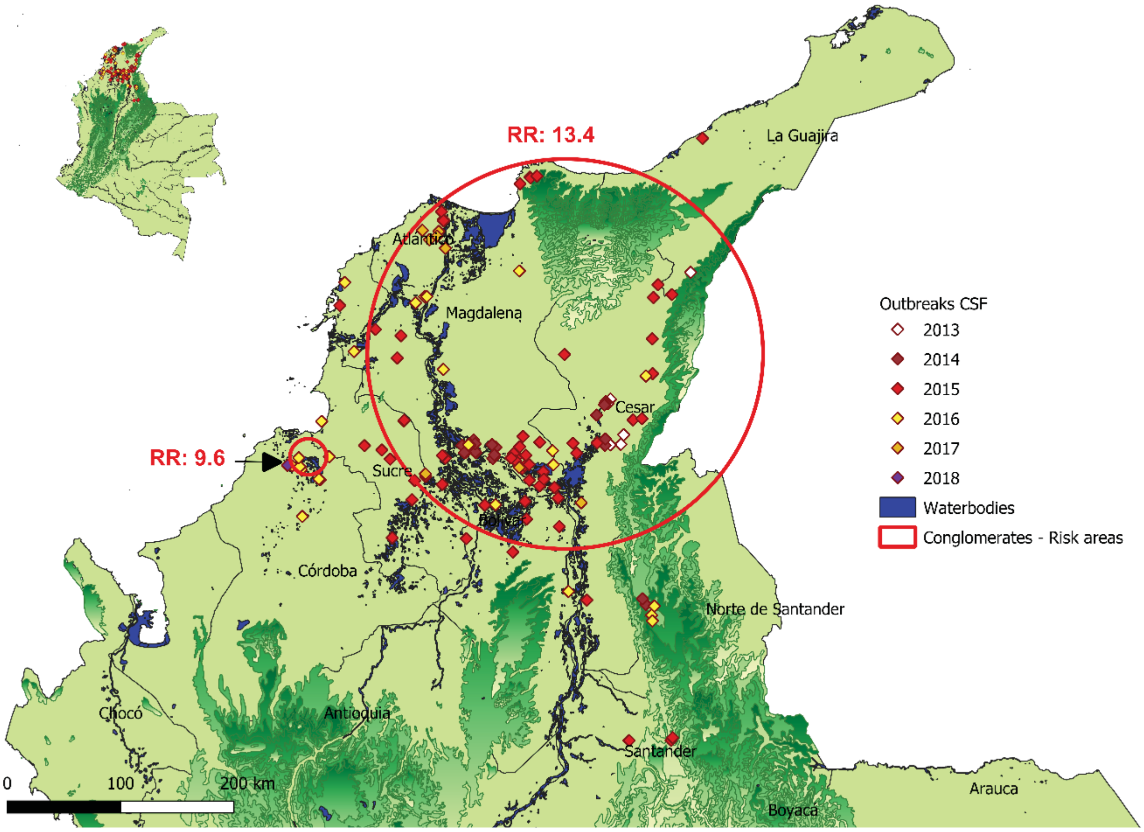

Fig 2. Areas of higher risk of infection with CSF

3.5 Discussion

Six years after the appearance of the last 3 outbreaks of CSF (June 2007 in La Guajira), the disease reappeared in the area of the Atlantic Coast, producing 134 outbreaks and causing a redirect of the health strategies that had been applied until that moment.

The origin of the first outbreak in 2013 was believed to be the illegal importation of infected pigs from Venezuela. This was based on the permeability of the border and the difference in pig prices between both countries at that time due to the socio-economic situation in Venezuela. The importance of the illegal trade between both countries is unknown, but the confiscation of 48.8 tons of pork meat and 778 live smuggled pigs by the Tax and Customs Police of Colombia in Guajira, Norte de Santander, Arauca, Bogota D.C., and Cesar between 2013 and 2018 (POLFA, 2019) suggests that it was not negligible.

Some conditions can explain the spread of the disease in these 9 departments. The most important is the high number of backyard premises. Backyard is the predominant production system in the Atlantic Coast and it is characterized by its poor management and health practices that favour spread of CSFV (Postel et al., 2018).

Much of the premises have free-range animals that leave free in the swamps until they have the right weight to be sold. Swamps occupy several departments of the Atlantic Coast and have a system of lagoons interconnected by pipes that in times of drought can be crossed by pigs. That was especially important between 2014 and 2016 due to meteorological disturbances produced by the El Niño phenomenon. This led to an increase of contacts between backyard pigs and eventually feral pigs together with an increase of animal movements on the Atlantic Coast to supply pastures. Backyard piggeries in the swamps of the Atlantic Coast and Magdalena River probably played an important role in the maintenance of CSF infection, and its dissemination to other areas, similar to the role of wild boars in Germany, transmitting either directly or indirectly CSFV to domestic pigs (Fritzemeier et al., 2000).

At the same time, pig movements between backyard premises are mostly out of control, and based on an informal pig trade, where pig traders go from municipality to municipality buying and selling pigs. Thirty-nine per cent of the outbreaks were attributed to animal movements, with this proportion being higher than the 13% of cases described in Germany in the 1990s (Fritzemeier et al., 2000), in Catalonia in 2001/02 (Allepuz et al., 2007) and the 17% reported in the Netherlands outbreaks (Elbers, A. R. et al., 1999). This difference is probably due to the idiosyncrasy of the backyard producers that usually move their animals between neighboring properties or through local merchants without any sanitary control.

Movements of people were the supposed cause of 37% of the outbreaks, also higher than the 23% described in Catalonia (Allepuz et al., 2007), the 10% obtained in Germany (Fritzemeier et al., 2000) and the 6% of the outbreaks occurred in Netherlands during the high risk period, or the 15% after the implementation of measures.(Elbers, A. R. et al., 1999). The main reason for this transmission was the low or no biosecurity in the backyard premises, where traders or other people entered pig pens without changing clothes, boots, or using disinfectants (Ribbens et al., 2004).

Other possible routes of transmission that have been described are by livestock trucks, contaminated swill feeding, movements of domestic animals other than pigs and neighboring premises, as have also been identified in commercial farms in Germany, Spain, and the Netherlands (Allepuz et al., 2007; Elbers, A. R. et al., 1999; Fritzemeier et al., 2000). These routes were not relevant in Colombia, probably due to the particularities of the backyard piggeries. The role of the neighbors, despite being important, is not reflected, since most of them are also part of the same epidemiological unit.

Only 31 (23%) outbreaks were linked with other affected premises. The most frequent cause of virus spread was the illegal movement of infected pigs (informal trade between backyard piggeries or pigs grazed together in swamps). The second most important link with affected herds were the entry of people or trucks, which is consistent with findings of Fritzemeier et al, (Fritzemeier et al., 2000) in secondary outbreaks in Germany and with that observed in the epidemic of CSF in Netherlands (Stegeman et al., 2002).

One of the problems of the disease control in the region was the time elapsed between the inspection by the veterinary service and the official declaration of the outbreaks. The median time was 15 days, much higher than in other emergencies (Allepuz et al., 2002; Elbers, A. R. et al., 1999). During this period, the premises were under quarantine but no other actions were taken, allowing the spread of the disease. The reason for this delay was the location of this laboratory in a CSF free zone. Due to protocol rules, samples were first sent to a laboratory located in Cucuta (Norte de Santander -vaccination zone) to inactivate the virus. In the last two years, a more efficient transport of samples has reduced the time to 8 days and 4 days in 2017 and 2018, respectively. Other measures, such as the involvement of more laboratories in the diagnosis, and new protocols were implemented to reduce this period.

The median time between the presentation of clinical signs and notification to the official veterinary service was 11 days, indicating that it takes several days to identify clinically or to suspect that they can be due to CSF. There may be two reasons that could influence this delay. The first one was the low number of animals in some premises, and the consequent difficulty for suspecting of an infectious disease; and the second one, the atypical or unspecific clinical signs that were present in most cases. This is compatible with Elbers et al.(Elbers, A. R. W. et al., 2010) who also identified limitations in the CSF suspicion report due to the lack of knowledge of the early signs of CSF. The owner of the animals made more than half of the suspicions. One of the explanations of this high number is that backyard producers do not have access to private veterinarians, and when they need advice, they contact the official services.

Despite that vaccination is compulsory in the area, 73% of the affected premises were not vaccinated. Veterinary authorities and the association of pork producers have made big efforts in the last 7 years, but the real vaccination coverage remains one of the main challenges in the zone. According to these organizations, a high vaccination coverage of up to 90% was achieved, but there are still an unknown number of premises that remain unnoticed, and without vaccination. The difficulties associated with vaccination coverage in remotes villages from rural areas and backyard premises has also been described by other authors (Blome, Moß, et al., 2017; Luo et al., 2014). In China, Luo et al (Luo et al., 2014), reported the incomplete vaccination coverage in remotes villages as one of the causes of CSF spread.

Twenty-seven percent of the affected premises had totally or partially vaccinated the animals. In some cases, disease occurred in weaning pigs due to the loss of colostral immunity (Suradhat et al., 2007b). Other reasons for failures in the vaccination process may be due to the application of the vaccine to healthy but infected animals, incomplete vaccination coverage in remote villages, or problems with the availability of the cold chain in remote areas.(Blome, Moß, et al., 2017; Luo et al., 2014).

CSF affects mainly backyard piggeries, with the same proportion (95%) that was described in Bulgaria. In this country they were responsible for infecting other backyards (13% infections), but they have a low impact on the transmission to commercial pig farms (Martínez-López et al., 2013). The CSF Eradication Plan in the Americas recognized that family pig producers with their small number of animals per owner but with a wide dispersion of premises, make disease control difficult.(The Classical Swine Fever Eradication Plan for The Americas, 2000). Likewise, Vargas-Teran et al. (Terán et al., 2004) pointed out that the geographical distribution of CSF in the Americas is related to the backyard production system, especially the extensive open field rearing systems with minimal care and feeding

The seven commercial farms that were infected by CSF had important failures in the vaccination. In three premises, animals had not been vaccinated against CSF, and the other four had been vaccinated only partially. The introduction of the virus was due to biosecurity failures (introduction of infected pigs, people, or domestic animals who acted as carriers). The situation in the backyard production is more complex, as despite the resources devoted to achieving a good vaccine coverage based on the application of the vaccine for free in these premises, a significant proportion of animals remain susceptible. Continuous efforts are made in the zone to update the census and to reach all premises.

Strengthening biosecurity measures in backyard farms is complex. In addition, they are mostly located in areas of waterbodies or marshes where pigs can be reared in close contact with free pigs. In this context, education campaigns on the disease directed to pig farmers and traders play an important role to ensure responsible pig ownership. Another important factor is the strengthening of vaccination strategies and epidemiological surveillance. Efforts should be done in high-risk areas and remote places to register populations that were previously unnoticed. The number of visits of people in charge of vaccination campaign to premises should be increased in order to maintain a high proportion of the population immunized and to monitor clinical signs. Finally, regular training of veterinary services, farm veterinarians and pig farmers in the recognition of clinical signs of CSF and differential diagnosis plays an important role to improve the efficiency of the CSF control program (Beltran-Alcrudo et al., 2019; Postel et al., 2018).

Mortality was between 31% and 39%, and the attack rate was between 38% and 48% depending on the age groups, except for sows that presented values of 17% and 21%, respectively. It can be attributable to the routine vaccination of adult animals, compared with piglets and with boars, which, in some cases are not vaccinated due to management problems. In the piglets' case, these are not vaccinated until they are older than 55 days of age, and in fatteners, vaccination or revaccination is not carried out because they are close to going to market. Several authors have shown that the severity of the disease depends on several factors such as infection and virulence, and host factors, such as age, genetic background, nutritional condition, and immune competence. (Blome, Staubach, et al., 2017; Leavens et al., 1998; Moennig et al., 2003); therefore, the morbidity and mortality that has been observed in the outbreaks is consistent with the presentation with an acute disease course.

The most frequent clinical signs described in the premises were fever, incoordination, prostration, grouping, cough, diarrhea, tremors, decay, weakness, conjunctivitis, and reddening of the skin, which are common with the acute form of the disease, as had also been observed in outbreaks in Spain (Catalonia), Belgium, the Netherlands, and Cuba (Allepuz et al., 2007; Blome, Staubach, et al., 2017; Elbers, A. R. et al., 1999; Fonseca et al., 2018; Moennig et al., 2003). In a small proportion of premises only respiratory, nervous, hemorrhagic, and digestive signs were observed, which are consistent with the typical signs of the disease. (Blome, Staubach, et al., 2017; Moennig et al., 2003).

In the spatiotemporal analysis, two clusters with a higher risk of infection were identified. The first and largest included a large part of the departments of Atlántico, Bolívar, Cesar, Magdalena, and Sucre, with a relative risk (RR) of 13.4 for the years 2014 to 2016. This is consistent with the endemic peak of the disease where 115 outbreaks occurred during these 3 years, and the advance of the infection towards the center of the Atlantic Coast and the swamps, and a second cluster grouped in municipalities of Chima and Lorica of the department of Córdoba, with a RR of 9.6 for 2016. This cluster included 9 outbreaks and its origin was due to the illegal movements of infected pigs and people.

The identification of clusters of high risk of infection with CSFV helps to strengthen and redirect the health strategies of surveillance, vaccination, and biosecurity, especially in backyard piggeries of these areas, in order to reduce the number of susceptible animals that can become infected and decrease the viral circulation of CSFV in the Atlantic Coast.

In conclusion, the Colombian epidemic of CSF was mainly related with the backyard production system. The affected region has an extremely high proportion of premises based on the subsistence economy. Despite the efforts of the veterinary services, there are no registers of an unknown number of backyard. Therefore, they are not covered by the vaccination campaigns neither the surveillance network. It is important to increase efforts to record as many premises as possible and to develop education campaigns including basic biosecurity measures, especially those related with animal movements.

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4. ESTUDIO II

Economic impact of Classical Swine Fever outbreaks between 2013-2020 in Colombia

Artículo en preparación

4.1 Summary

Classical swine fever is one of the diseases with the greatest impact in the swine health and industry. In the 90s the CSF outbreaks occurred in several countries of the European community caused significant losses, as is the case of the Netherlands where the epidemic caused losses of US $ 2.3 trillion, while in Germany and Belgium were estimated losses of 1 trillion and 11 million euros respectively. The objective of this study is to assess the economic impact of 156 CSF outbreaks that occurred between 2013 and 2020 in the country, based mainly on information from the ICA and the Colombian Association of Pig Farmers – Porkcolombia. The direct costs of the disease, outbreak control activities, vaccination, active and passive surveillance activities and the costs of training and awareness campaigns were assessed. The outbreaks caused a total cost of US $10.2 million, where the cost of disease and outbreak control activities was US $466,473 concentrated mainly on inspection of affected, neighboring and contact farms, payment of compensation and direct costs of the disease. Visiting the affected and neighboring farms had an average cost per outbreak of US $395 and US $903 respectively, while US $83 was spent on diagnostic tests and US $963 on movement control per outbreak. In 39 outbreaks, animals were stamped out with an average cost per outbreak of $2,645. However, the biggest cost of the control measures was the vaccination of pigs, between 23,000 and 235,000 farms were vaccinated annually with an average annual cost of US $9.2 million (US$8.5 per farm). The cost was mainly due to the hiring vaccinators with a cost between 0.8 to 1.2 million annually. The outbreaks caused direct losses to producers due to death animals of US $148,059. The total cost of surveillance in the affected area was US$1,047,906 which includes the value of active surveillance in high-risk facilities and the inspections performed in farms reported as CSF suspicious. In conclusion, the annual cost of the outbreaks in Colombia was cheaper than the cost described in other countries, mainly because animals from infected farms were not slaughtered, but on the other hand, the measures applied have not been enough efficient to the eradicate the disease.

4.2 Introduction

Classical swine fever (CSF) is one of the diseases with the greatest impact in the swine health and industry (OIE, 2009; Ribbens et al., 2004). Some countries are officially recognized as disease free by the OIE: the European Union except Romania and other countries from Western Europe, Kazakhstan in Asia, Australia, New Caledonia and New Zealand in Oceania, North America, Canada, Mexico, Costa Rica, Argentina, Chile, Paraguay, Uruguay and some areas of Brazil and Colombia (OIE, 2021b). Between 2019 and June of 2021, 3.523 outbreaks were reported worldwide, causing 4.757 dead pigs, with the Asia and Americas being the most affected regions with 3.322 and 183 outbreaks and 2.232 and 2.517 dead animals respectively. The countries with the highest number of outbreaks in that period were: Japan (3.117), Indonesia (133), Vietnam (59), Peru (44), Brazil and Peru (44 each), Cuba (43), Colombia and Ecuador (20 each) (OIE, 2021a).

The disease is controlled mainly by immunization with attenuated vaccines and the slaughter or depopulation of infected farms (Moennig, 2000); accompanied by strategies of clinical and virological surveillance, movement restriction, cleaning and disinfection. (OIE, 2021d). In the 90's, the European Community based the CSF control on the strategy of non-vaccination and depopulation of infected farms (DIRECTIVA 2001/89/CE DEL CONSEJO de 23 de Octubre de 2001 Relativa a Medidas Comunitarias de Lucha Contra La Peste Porcina Clásica, 2001), which led to epidemics in areas with high density of pigs causing high economic losses (De Vos et al., 2005; Edwards et al., 2000; Moennig, 2000). In the Netherlands between 1997-1998 there were 429 outbreaks that led to sacrifice 700.000 pigs (Elbers, A. R. et al., 1999); the cost of these epidemics was estimated at US $2.3 trillion, where losses for producers and industry were US $423 million and 596 million respectively (Meuwissen et al., 1999); the disease spread to Belgium, It was estimated that the 8 outbreaks in this country had a total cost of €11 million (Mintiens et al., 2001). In Germany, between 1990 and 1998 424 CSF outbreaks were declared, producing economic losses of about 1 trillion Euros (Fritzemeier et al., 2000).

In Latin America, FAO (2003) estimated the impact of CSF between 1997 and 2001 due to animal mortality in three Latin American countries, it was US$1,000,000 in Mexico, US$140,000 in Brazil and US$390,162 in the Dominican Republic. In Chile, the direct losses due to morbidity and mortality during the period of eradication of the CSF (1983-1997) were estimated to reach US 2.5 million (Pinto, 2000).

The CSF is still now a latent problem in several Latin American countries where new outbreaks are diagnosed mainly on backyard premises. The disease supposes direct and indirect costs for producers, the swine industry and veterinary administrations. It also supposes a latent risk of markets closure for countries such as Brazil and Colombia that have opted for the zonation strategy and that have achieved an important growth of the meat pork production in the recent years. Different problems have been identified in Latin America affecting the progress of the control strategies: the spread of moderate virulence strains that produce subclinical or chronical infections with mild clinical signs (Fonseca et al., 2018; Terán et al., 2004), deficiency in coverage and updating of records and information of subsistence production systems (de Oliveira et al., 2020) and informal marketing of pigs (de Oliveira et al., 2020; Pineda et al., 2020; Terán et al., 2004).

From the reintroduction of CSF in Colombia in 2013 to 2020, 156 outbreaks have been declared in the non-free area, which have led to high costs for the pig sector and veterinary service due to mortality, compensations, vaccination costs, diagnosis, epidemiological surveillance etc. The objective of this work is to estimate the economic impact of the outbreaks of Classica Swine Fever over the past 8 years.

4.3 Materials y Methods

4.3.1 Population

Colombia has a population of 6.7 million pigs (ICA, 2021). Different production systems coexist in the country, from backyard premises with scavenging pigs to modern commercial farms.

This study focuses on the departments that had CSF outbreaks, mainly from the Atlantic Coast region that comprising seven departments with a very high proportion of backyard premises (99.5%) (Table 1). The production in this region is characterized by subsistence premises with low levels of health and biosecurity, part of these pigs are free range populations in swamps o waterbodies that only go to the settlements to feed. Some CSF outbreaks have been declared also in the departments of Norte de Santander and Santander, which have 41% of the census and 12% of premises classified as commercial farms.

Table 1. Population of pigs and pig farms in the departments affected by CSF

Department	Backyard premises		Commercial farms		Total	
	No pigs	No premises	No pigs	No farms	No pigs	No farms
Atlántico	86,936	4,826	111,304	212	198,240	5,038
Bolívar	300,495	24,429	3,766	7	304,261	24,436
Cesar	98,261	8,726	6,056	29	104,317	8,755
Córdoba	404,437	42,639	15,822	24	420,259	42,663
La Guajira	39,058	3,261	11,012	293	50,070	3,554
Magdalena	266,784	17,382	8,660	11	275,444	17,393
Sucre	231,266	29,482	523	3	231,789	29,485
Total Atlantic Coast	**1,427,237**	**130,745**	**157,143**	**579**	**1,584,380**	**131,324**
Norte de Santander	32,119	9,263	52,004	1,522	84,123	10,785
Santander	65,509	3,214	15,646	48	81,155	3,262
Total others	**97,628**	**12,477**	**67,650**	**1,570**	**165,278**	**14,047**

Source: Pig Census – National Livestock Census-2020. Colombian Agricultural Institute - ICA. (ICA, 2021)

Classical swine fever is circumscribed to the northern region, while it is absent in the other parts of the country. The vaccination was suspended in this area in May/2013 after 6 years without cases and one month later appears the first case; a health emergency was declared in the surrounding area and measures to control de outbreak including vaccination were carried out. In August/2014 vaccination was re-established on the Atlantic Coast region since the infection had already spread to several departments.

4.3.2 Source of information

The information about the 156 CSF outbreaks occurred in the country between 2013 and 2020 was obtained by the veterinarians of the Official Veterinary Service (ICA) using two questionnaires: the first corresponds to the report of suspected outbreak and the second when it was confirmed as positive. These questionnaires include information on farm characteristics, affected population (susceptible, sick and dead), vaccination status, samples collected and diagnostic tests performed. Information about the costs of activities related to the control of outbreaks, the surveillance, the movement control, diagnostic tests and training activities were also provided by ICA

The Colombian Association of Pig Farmers (Porkcolombia) is the entity responsible for carrying out vaccination in the country and provided information on the costs of purchasing vaccines, vaccination logistics and hiring vaccinators, as well as the number of farms vaccinated.

Information of animal prices and production costs in backyard premises of the affected area was obtained with a survey applied to 180 backyard producers from the affected departments and it was collected by Porkcolombia field officials.

4.3.3 Impact assessment

Direct costs of the disease: Death and reduction of animal production were the most important direct costs; it was assumed by the producer and it was evaluated as the average price of pigs according to their age category according to the data collected in the survey.

Costs of control activities in affected farms: These are divided into: a) the operational costs to detect and track the disease. It includes the time spent by the ICA officials in the outbreak investigation in the affected premise and in the neighborhood (usually the small village was considered as an epidemiological unit and defined as a single outbreak) and costs derived from the diagnosis (sampling, transport and diagnostic tests); b) culling and disposal of carcasses, that includes the time taken by officials and support staff to sacrifice the animals and carcass disposal and c) compensation to producers i.e. the price of the kg of meat paid by the ICA according to the type of animal.

The first outbreaks in 2013-2014 period were stamped-out according to the policies applied in case of a health emergency in zone without vaccination, while in the subsequent outbreaks the decision to sacrifice animals was applied in 4 outbreaks according to their epidemiological situation and based on the ICA criteria.

Vaccination costs: Costs incurred in purchasing vaccines, hiring vaccinators, travel expenses and cost of logistics to maintain the cold chain. The yearly vaccination campaign in Colombia last 4 months (except in 2013 and 2014 which lasted only 1.5 months). In the remaining months a reduced staff is responsible of vaccinating the animals that had not been vaccinated during the campaign.

Costs of surveillance activities: Two types of activities were considered: active surveillance carried out in high-risk places (backyard premises and animals fairs) and investigation of suspicious cases of CSF detected by passive surveillance. In both cases, the cost of salaries of the staff who visited the farm, materials and equipment, the cost of diagnostic tests and the transport of the samples were considered.

Costs of training and awareness campaigns: training and awareness-raising activities for producers and professionals in the sector were considered. It included the cost of the salaries of the personnel who attended the activities.

The main costs and units considered in the different items are listed in Table 2. All prices were adjusted to the value of Colombian Peso in year 2020, with an inflation calculator considering de consumer price index to remove distortions due to inflation.

Table 2. Mean cost and units by outbreak of the different items included in the economic analysis

Measure	**Item description**	**Units**	**Unit cost US$**	**Abbreviation**
Control activities in outbreaks				
Visits to the premise to diagnose and control	Time spent by veterinarians (two veterinarians/ 1days per visit, including trip)	4 visits	69.71	VisOut
	Materials for sampling	4 samples/4 times	20.32	MatSam
	Transport samples	4 times	8.63	TransSam
	cVisit= 4* (visOut + 4*MatSam + Transsam)			
Visits to neighboring and contact farms	Time spent by veterinarians (four veterinarians/ 5 days, including trip)	1 vet per day	38.76	VisNeig
	Materials for sampling	5	20.32	MatSam
	Transport samples	3	8.63	TransSam
	cContact = 4*5*VisNeig + x*MatSam + x*TransSam			
Diagnostic tests	Elisa	1 to 4	4.1	Elisa
	PCR	1 to 4	19.9	PCR
	Viral isolation (VI)	1 to 3	26	VI
	Histopathology	1 to 2	14.9	HP
	cDiag = n* Elisa + n* PCR + n*VI + n*HP (n depends on farm size)			
Control of movements	Time spent (two persons / 15 days)	1 person/day	28.36	PersMov

	Disinfectants	total	729.72	MatDesin
Carcasses disposal	Time spent veterinarian and support personal to culled pigs (one veterinarian and two workers)	1	73.9	PersCulled
	Method of sacrifice by electrocution		0	MetCulled
	Cost of burial and disposal animals according to quantity of pigs (workers or excavator)	1	8.59 - 139.4	DispAnim
Compensation to producers	Compensation for type and weight of animal (piglets to breeding or breeding sows)	1	21.41 - 239.26	CompAnim
Direct cost al farm level				
Losses by death animals in outbreaks	Losses for type animal (piglets to breeding or breeding sows)	1	29.73 - 151.44	LossDeath
Control activities in non-affected farms (cost per year)				
Vaccination in farms				
Vaccine cost	purchase cost of vaccine dose	10,614,505	0.20	Vaccine
Vaccinators	Cost of vaccinators per campaign	129 – 356*	368.33	Vaccinators
Maintaining cold chain	Payment for storage and cold chain of the vaccine	358 -376*	102	ColdChain
Surveillance activities				
Visits high risk places	Time spent by veterinarians (one veterinarian/ 0.5days/visit, including trip)	2.247 - 8.212*	21.98	VisHRP
Investigation of negative suspected outbreaks	farm visits with suspected CSF reports (including time spent, trip, materials sampling, transport samples and diagnostic test) by year	104 – 210*	121.21	VisSusp
Training and awareness campaign				
Training cost	Training and awareness activities for veterinarians and producers by year	65 – 147*	14.18	Training

* depending on the amount per year

4.4 Results

The 156 CSF outbreaks declared in Colombia in the 2013-2020 period have caused an economic cost to the country of US $10.2 million, i.e. an average annual cost of 1,35 million (Table 3). The cost of the disease and the control activities conducted in the outbreaks was US $466 473 and supposed a small part (4,6%) of the total cost. The losses due to the death of 2601 pigs was US $148,059 and the visits to neighboring and contact farms supposed US $140 803. Visiting the affected farm and neighboring farms had an average cost per outbreak of US $394.5 and US $902.5 respectively and the diagnostic tests costed US $82.7 per farm. In the 37 outbreaks where animals were stamped out, the mean cost per outbreak was 2,645

Stamping out was applied in some outbreaks, mainly in years 2013-2014 and some outbreaks in 2017 and 2018, they received a total of US$ 98.950 for the 2.494 pigs that were destroyed. Other expenses for these producers were the personnel hired to destroy the carcasses and the disinfectants. In farms where animals were not destroyed other costs as loss of production of diseased animals and diseased pigs that died after the last visit were not recorded and therefore they could not be calculated.

Table 3. Costs due to the disease and control activities in outbreaks (US $ converted to the 2020 prices)

Year / Cost	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Total**
No outbreaks	9	24	63	28	8	2	20	2	156
Susceptible pigs	593	1,144	2,290	1,293	2,014	87	380	48	7,849
Sick pigs	113	645	1,093	813	171	50	261	18	3,164
Death pigs	76	555	855	775	102	38	190	10	2,601
Culled pigs	517	589	0	0	1,377	11	0	0	2,494
Losses death animals	5,019	32,728	47,862	44,566	5,619	1,449	10,199	616	148,059
Compensation cost	43,350	50,707	0	0	4,184	709	0	0	98,950
Cost disposal carcasses	1,001	2,386	0	0	723	108	0	0	4,219
Cost visit premise outbreak	3,552	9,471	24,854	11,050	3,157	789	7,884	789	61,547
Cost visit farms neighbors	8,123	21,662	56,863	25,272	7,221	1,805	18,052	1,805	140,803
Cost diagnostic test	1,076	1,906	5,241	2,483	672	169	1,184	165	12,895
Total cost	**62,121**	**118,860**	**134,820**	**83,371**	**21,575**	**5,030**	**37,319**	**3,376**	**466,473**

The highest cost of the CSF control were the measures applied in the general population, especially the vaccination of the pig population. Between 23,000 and 235,000 premises were vaccinated yearly (Table 4) with a total cost US $9.2 million (US $8.5 per farm and year present in the zone) representing a 90% of the total cost. The cost has been concentrated mainly in hiring vaccination teams (between 0.8 to 1.2 million annually).

The total cost of surveillance in the region was US $1,047,906, and it included the cost of the active surveillance activities performed in high-risk premises (933,602) and 1.197 visits performed to farms with suspected CSF reports in the frame of passive surveillance (US $114,304). The 653 training and awareness- raising activities aimed at producers and veterinarians in the region had a total cost US $9,260 (Table 4).

Table 4. Costs of the vaccination and surveillance activities in areas with outbreaks

Year	No vaccinated farms	Cost movement control	Vaccine cost	Cost vaccination teams	Cold storage chain cost	Active surveillance cost- high risk places	Passive surveillance cost- attention to reports	Training cost	Total cost
2013	22,953	9,483	60,622	304,187	36,130	49,381	13,212	0	463,532
2014	60,722	22,127	106,756	396,295	36,130	103,091	12,970	0	655,241
2015	89,016	42,674	237,637	809,935	36,130	81,137	17,818	1,205	1,183,861
2016	175,762	34,772	350,814	1,285,670	36,130	131,704	19,879	2,014	1,826,209
2017	137,096	2,644	324,022	1,146,092	36,130	116,013	12,121	2,084	1,636,462
2018	150,094	3,161	307,639	828,443	36,130	164,383	14,788	1,999	1,353,381
2019	234,424	22,127	423,435	941,020	36,130	144,143	13,697	1,035	1,559,460
2020	212,157	3,161	313,031	1,076,251	36,672	143,752	9,818	922	1,580,446
Total area outbreaks	**1,082,224**	**151,150**	**2,123,955**	**6,787,892**	**289,579**	**933,602**	**114,304**	**9,260**	**10,258,591**

4.5 Discussion

The US $10.8 million cost of CSF in 8 years in the affected areas is much lower than the cost of outbreaks of this disease described in European countries such as the US $2.3 trillion that costed in the Netherlands (Elbers, A. R. et al., 1999; Meuwissen et al., 1999), € 1 trillion in Germany (Fritzemeier et al., 2000), or similar to the € 11 million that costed only 8 outbreaks in Belgium (Mintiens et al., 2001). But they are higher than the US 2.5 million cost of the disease in Chile (Pinto, 2000).

The smaller cost in Colombia than in Europe was due mainly to two reasons: The first one was the application of stamping out policy only in 37/156 outbreaks mostly at the start of the circulation of the virus between 2013 and 2014. This decision to not sacrifice all the affected premises and any neighbor or contact may have contributed to the continuous CSFV circulation in the region of Atlantic Coast for so long. The compensation procedure was applied until 2017 into the CSF contingency plan and it was subject to a previous ICA evaluation, since in some case the producer was not compensated, this can contribute to a discouragement of reporting and lack of trust in institutions. The second reason is the size of the affected farms: most outbreaks appear in backyard premises with a small number of animals (the median of the census in the outbreaks was 25 animals, including piglets).

The direct cost of the disease was only partially evaluated, because we had access only to the mortality but not to the abortions and loss of productivity of the animals. Despite this partial information, we can assume that the direct cost was relatively low compared with the total cost, mortality is the highest direct cost and it represents 148,059 US$ (1.5% of the total cost).

The cost of the activities performed in affected and epidemiologically related farms was also relatively low (4.3% of the total) and it included the visits to outbreaks and related farms and the stamping out.

The highest cost of the disease control was the preventive measure applied in the region, especially the vaccination on farms that supposed 90% of the total cost in the affected region. The highest expenditure (66%) was the cost of hiring the personnel in charge of de vaccination campaign (between 130 and 500 vaccinators depending on the year). During the first outbreaks a ring vaccination was carried out by 130 vaccinators in an area of 10 km of radius. After the spread of the disease to other departments of the Atlantic Coast, in August 2014 it was decided to restart vaccination in the all the region and since 2015 a team of approximately 350 vaccinators has been maintained. Vaccination is financed by the national pig farming fund, through a tax paid by commercial pig producers in the country.

The high number of backyard premises in the region had an important effect on the spread and maintenance of the disease due to their idiosyncrasy. One of the problems of the backyard production in the region are the movements of animals between premises and to the slaughterhouses with any administrative authorization spreading the infection through the region. To reduce these uncontrolled movements, mobile checkpoints were installed near the outbreaks covering the main routes to reduce this informal movements of animals with a total cost of US$ 150,000.

The consequences of the direct loss due to death of animals and the consequent lack of income from the sale of the animal or return on investment can be huge for the backyard or subsistence producers (149/156 of the outbreaks). Backyard producers of this region have a socio-economic condition of vulnerability, and their risk to be affected by CSF is higher than commercial farms as had been observed in Brazil where the 68 CSF outbreaks that occurred between 2018-2019 also occurred in this type of production systems (de Oliveira et al., 2020). Or in in Peru where there was a significant association (OR 1.52) between the human development index (HDI) and the probability of CSF occurrence. (Gómez-Vázquez et al., 2019).

The impact of transboundary animal diseases can be important in this type of small holders, as it has been described in ASF outbreaks, they can suppose the stop of pig production due to a lack of money to buy news pigs and the fear of new outbreaks. In some cases families can become poor and have effect on the education of the children, on the medical care and a decrease in the meat content in the diet. For many smallholders pigs represent an emergency bank to cover emergencies or major expenses (Chenais, Boqvist, Sternberg-Lewerin, et al., 2017; Smith, D. et al., 2019). To a lesser extent, producers of commercial farms were also affected, which could have greater indirect losses associated with the days without production, however, no analysis could be carried out due to the lack of productive information on the farms.

Selling or eating the meat of dead animals has been described as a way to reduce the monetary effect of the disease on the backyard producers (Chenais, Boqvist, Emanuelson, et al., 2017; Leslie et al., 2015), we do not have information, as we obtained information only from official sources, there is any evidence of this activity because it is forbidden, but we can assume it was done in some cases.

The most important limitation of this study is the lack of follow-up of the outbreaks that were not stamped out, with the consequent loss of information about animals that die and about the impact of the CSF on the growth parameters of survivors.

As a conclusion the cost of the outbreaks in Colombia was $10 million, cheaper than other countries, mainly due to not slaughtering the animals on infected farms. Vaccination was the most expensive measure, due to the hiring of a group of vaccinators for several years. The measures against the disease should be reinforced in order to eradicate the disease and to stop the vaccination in a medium-term period. Due to their vulnerability, the disease has an important economic impact on backyard producers and measures should be applied to reduce its economic impact.

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5. ESTUDIO III

Evaluation of the sensitivity of the classical swine fever surveillance system in two free zones in Colombia

Transboundary and Emerging Diseases. 2021;00:1–13.
https://doi.org/10.1111/tbed.14092

5.1 Summary

Infection with the Classical Swine Fever Virus (CSFV) causes a disease in pigs that ranges from a hyperacute form in which animals die in a few hours to subclinical disease. Due to this wide range of virulence, several complementary surveillance strategies should be implemented for the early detection of the disease. The objective of the present study was to determine the sensitivity of the surveillance system to detect CSFV outbreaks in a free zone (Zone 1) and in a zone undergoing an eradication process (Zone 2) in Colombia. Stochastic scenario tree models were used to describe the population and surveillance structures and to determine the probability of CSFV detection. The total sensitivity of the surveillance system in the case of a single infected farm in Zone 1 was 31.4% (CI 95%: 7.2 -54.1) and in the case of 5 infected farms was 85.2% (CI 95%: 67.3 -93.7), while in Zone 2 the sensitivities were 27.8% (CI 95%: 6.4- 55.1) and 82.5% (CI 95%: 65 - 92.9) respectively. The on-farm passive surveillance shows the highest sensitivity for detection of a single CSFV infected farm in both zones (22.8% in Zone 1 and 22.5% in Zone 2). The probability of detection was higher in a family / backyard premise than on a commercial farm in both zones. The passive surveillance at slaughterhouse had a sensitivity of 5.3% and 4.5% for the detection of a single infected farm in Zone 1 and 2 respectively. Active surveillance presented a range of sensitivity between 2.2 and 4.5%. In conclusion, the sensitivity of the surveillance in the two studied zones was quite high, one of reasons for this good sensitivity being the sentinel network based on the voluntary participation of 5,500 collaborators that were trained for the identification and notification of diseases of national interest.

5.2 Introduction

Classical Swine Fever (CSF) is one of the most important diseases in pigs, with major impact on animal health and on the swine industry (Blome, Staubach, et al., 2017; Penrith et al., 2011). It is caused by the CSF virus (CSFV), an enveloped RNA virus classified in the family *Flaviviridae*, genus *Pestivirus* (OIE, 2009; Ribbens et al., 2004). CSFV affects only pigs and wild boars and can be transmitted both horizontally and vertically. CSFV infection can have a wide range of severity, from a chronic course to a hyperacute presentation in which animals die in a few hours. The clinical signs and lesions can vary among animals depending on the virulence of the CSFV strain and on such host factors as age, breed and immune status (Blome, Staubach, et al., 2017; Moennig et al., 2003; Petrov et al., 2014b). This variability in disease presentation forms and unspecific clinical signs means that the detection of the disease in free populations is not always easy and consequently, epidemiological surveillance should be based on different strategies. The CSF surveillance program should cover domestic and wild pig populations and should include an early warning system throughout the whole production chain, especially with regard to high-risk groups (OIE, 2019).

Active and passive surveillance refers to the method of data collection depending on whether the data provision is investigator-initiated (active) or observer-initiated (passive) (Dufour, B., Hendrikx, 2009).

Surveillance systems must be evaluated and optimized to improve their effectiveness regarding the data quality, costs, and resources used. A good indicator to assess their effectiveness is the sensitivity (Se) of the surveillance system components, which has been defined as the probability of detection of the disease (or infection) if present at a certain level in the population. (FAO, 2014; Hoinville et al., 2013). This level is known as design prevalence and represents the “threshold prevalence” from which the disease can be detected (Martin, Cameron, & Greiner, 2007). The sensitivity of the surveillance depends on different factors such as the sensitivity (Se) and specificity (Sp) of the diagnostic test, on the number of animals included in the surveillance and on different circumstances related with activities performed (n).

CSF is still a major problem in some regions of Colombia. The country has been divided by CSF status into different epidemiological zones: a zone recognized as CSF free by the OIE, some zones undergoing an eradication process without vaccination and an affected zone where vaccination is compulsory (ICA, 2018). Despite the strict control of internal movements, the presence of the disease in the country supposes a major risk for the free zones. Surveillance is basic for achieving early detection of CSFV and the application of immediate measures to eradicate the infection (Donahue et al., 2012).

The objective of the present study was to determine the sensitivity of active and passive surveillance in the detection of CSFV infection in the two free zones in Colombia.

5.3 Materials and Methods

5.3.1 Reference population

Colombia is located on the equator in the northwestern region of South America. With a swine population of 5.5 million head, different production systems coexist in the country from free range backyard facilities to large industrial farms. CSFV is still present in a part of the country, specifically in the Atlantic Coast region where it is endemic, while the infection is absent in the other regions. However, the status differs: while in some regions vaccination is compulsory, in other zones it is prohibited. This paper focuses on two regions declared as free either by the government or by the OIE. (Figure 1). The free zone recognized by the OIE (Zone 1) includes 13,500 farms (15.5% of the total for Colombia), and the zone undergoing an eradication process (Zone 2) has 20,352 farms (25.6%). According to the database of the Colombian Association of Pig Farmers (Porkcolombia), 24% and 12.4% respectively are commercial farms, while the remainder are other family and backyard premises. (Table 1).

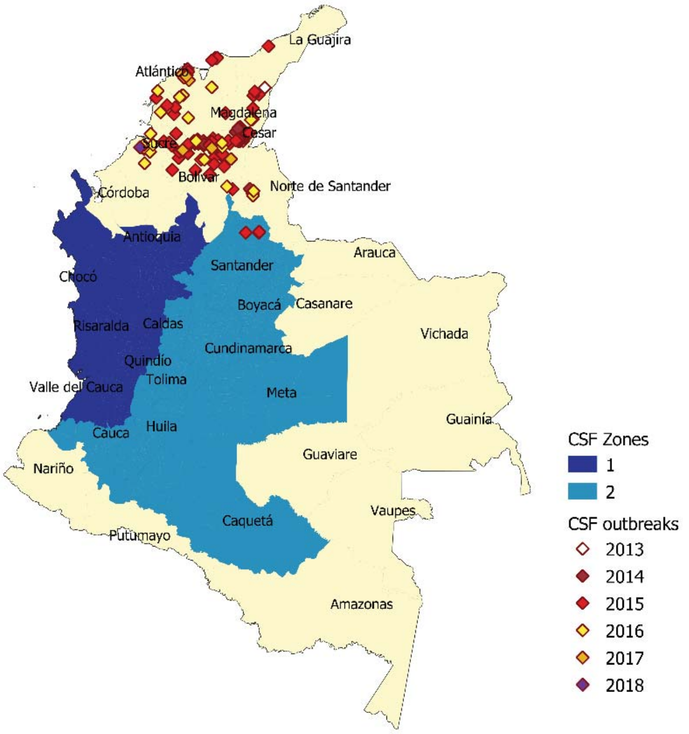

Figure 1. Map of Colombia with Zones 1 and 2 and CSF outbreaks occurring in the 2013-2018 period

5.3.2 The Colombian surveillance system

In Colombia, CSF is one of the notifiable diseases in the country and it is subject to official control, with active surveillance supporting disease control. Other than reporting by farmers and veterinarians, passive surveillance is based on a sentinel network created by the ICA (national veterinary services) as a component of its early warning system for diseases under surveillance (both endemic and exotic diseases). The purpose of the network is to increase the capacity to detect diseases in the country, and it is based on a participatory information system made up of 5,500 collaborators (farmers, technical assistants, veterinarians, farm managers and anyone else involved in the sector). People participate on a voluntary basis and have been trained by the ICA for the identification of clinical signs and reporting of diseases of national interest. The information is monitored, collected, and analyzed by the epidemiology section of the ICA. In zones 1 and 2, the network is made up of 1,247 and 2,386 members respectively, who are mostly paraveterinarians, veterinary practitioners and animal identification handlers (people hired by Porkcolombia to individually identify pigs on farms) (ICA, 2019c). Passive surveillance is also applied at slaughterhouses and is based on the detection of clinical signs of CSF in ante and postmortem inspection by veterinarians. Epidemiological sampling for active surveillance of CSFV is performed yearly throughout the second semester. In this paper, we evaluate the activities performed in 2018 and 2019 in zones 1 and 2. The parameters for sample size in 2018 and 2019 in Zone 1 were: farm prevalence of 1% per each of the 5 categories into which farms are classified and an animal prevalence of 20% on commercial technified and genetic nucleus farms, 30% on commercial-industrial and family farms and 50% on backyard premises with a 95% confidence level. In Zone 2, the farm prevalence was fixed at 3% in 2018 and 1% in 2019 and animal prevalence was 20% in commercial technified, 30% on commercial-industrial and family farms and 50% for backyard premises. In the 2019 design, the same parameters were used, except for 1% farm prevalence and 60% animal prevalence on backyard premises. The number of farms and pigs sampled in both areas is shown in Table 1.

Table 1. Number of premises and individual pigs sampled for CSF active surveillance in both zones between 2018 and 2019.

Category of premises *	**Zone 1**					**Zone 2**				
	Number of farms	**2018 Design**		**2019 Design**		**Number of farms**	**2018 Design**		**2019 Design**	
		Sampled farms	**No of pigs**	**Sampled farms**	**No of pigs**		**Sampled farms**	**No of pigs**	**Sampled farms**	**No of pigs**
Genetic nucleus	18	18	270	17	255	4	4	60	3	45
Commercial technified	859	257	3,855	258	3,870	231	67	1,005	155	2,325
Commercial-industrial	2,365	66	660	91	910	2,292	49	490	66	660
Family	5,245	170	1,710	180	1,800	8,435	170	1,700	243	2,430
Backyard	5,013	240	1,200	252	1,260	9,390	206	1,030	310	1,240
Total	**13,500**	**751**	**7,695**	**798**	**8,095**	**20,352**	**496**	**4,285**	**777**	**6,700**

* Farms grouped according to Government categories: Genetic nucleus (all should be tested), technified (farms with ≥100 sows and/or ≥600 fatteners), commercial-industrial (10-100 sows and/or 100-600 fatteners), family (3-10 sows and/or 15-100 fatteners) and backyard (≤3 sows and/or ≤15 fatteners).

5.3.3 Scenario tree model (STM)

The sensitivity of the surveillance system was calculated using a stochastic scenario tree model that describes the population and surveillance structures. The model represents all the elements involved in the different components of the surveillance network applied to the study population (FAO, 2014; Martin, Cameron, Barfod, et al., 2007).

For each component of the surveillance system, the scenario tree defines a sequence of logical nodes with a different branch for each subpopulation considering the probabilities of infection and detection. The nodes are classified as infection, detection or risk nodes. The model is used to evaluate the probability of a randomly selected unit in the system giving a positive result.

Three design prevalences were set at 1, 5 or 10 affected herds respectively, a single affected farm corresponded to a prevalence of $7.4*10^{-5}$ and $4.9*10^{-5}$ in zones 1 and 2 respectively. We assumed that the herd prevalence ($P*_H$) and the within-herd prevalence ($P*_A$) would be similar to those observed in the outbreaks of CSF detected on commercial farms and backyard premises in other regions of Colombia between 2013 and 2018 (Pineda et al, 2020). The detection nodes represented all the events or steps that had to occur to detect the infection, while the risk nodes represented those factors that affected the probability of becoming infected or detected. The diagrams of the scenario trees for the three surveillance components are shown in Figure 2.

Table 2 shows the parameters included in the model. The relative risk for each category (commercial - family) was obtained by dividing the cumulative incidence on backyard and family farms by the incidence on commercial farms (reference category) observed in other regions of the country.

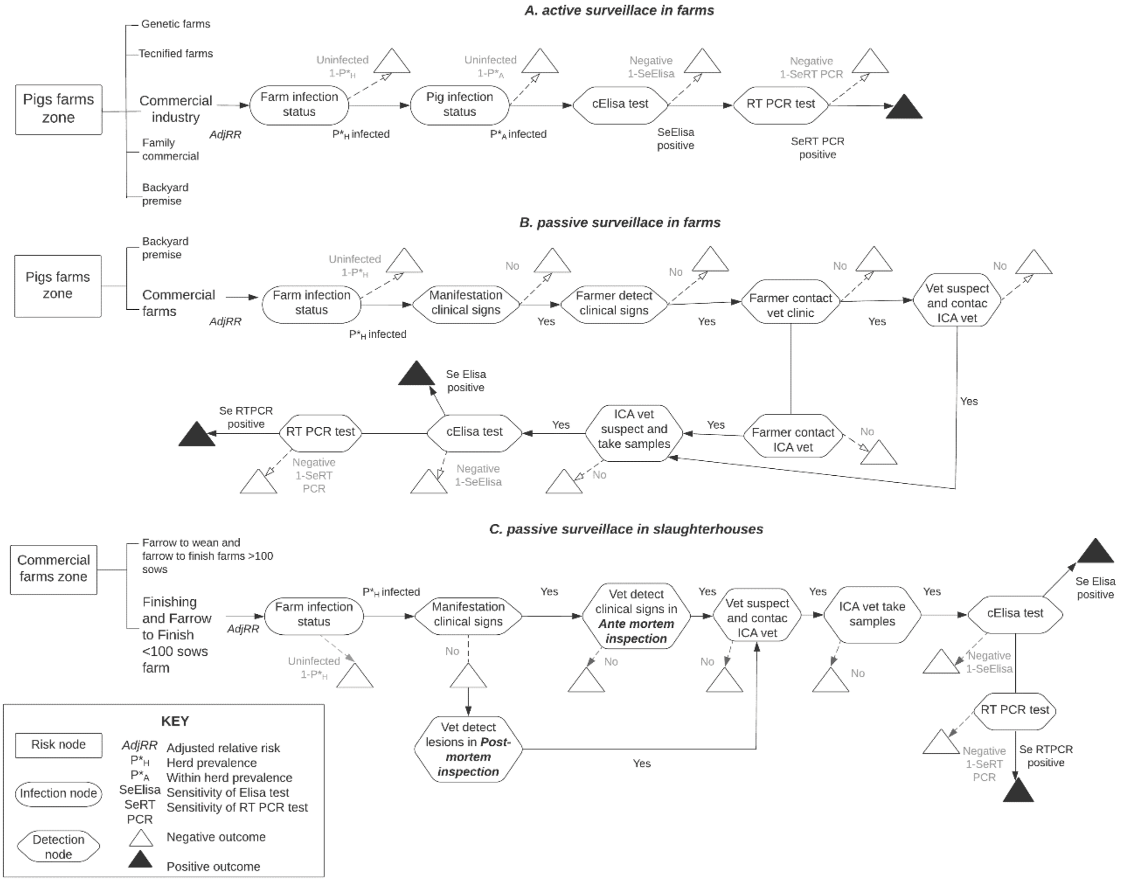

Figure 2. Scenario trees for active and on-farm and at slaughterhouse passive surveillance. Only the branch for commercial farms is represented, the others being of identical structure.

Table 2. Variables and parameters included in the active and passive surveillance models

Node	Parameter	Abbreviation	Values and probability distributions in ZONE 1	Values and probability distributions in ZONE 2	Simulations distribution	References or sources of data
Variables and parameters common to the different paths						
Farm type	Number of commercial farms		3242	2527	Fixed value	Farms database - Porkcolombia
	Number of backyard premises and family farms		10258	17825	Fixed value	Farms database - Porkcolombia
	Proportion of commercial farms	PrP_c	999.9; 3164.5	999.9; 7058.5	Beta◆	Farms database - Porkcolombia.
	Proportion of backyard premises and family farms	PrP_b	999.9; 316.5	999.9; 142.4	Beta◆	Farms database - Porkcolombia.
Farm infection status	Design prevalence (for 1 infected farm)	P*	7.41E-05	4.91E-05	Fixed value	Zone 1: 1 /13500 farms; Zone 2: 1/20352 farms
	Farm level prevalence (commercial) (R_2)	P^*_{Hc}	7.7; 8667.5		Beta◆	7/8976 CSF outbreaks on commercial farms (Pineda et al, 2020)
	Farm level prevalence (backyard) (R_1)	P^*_{Hb}	128.8; 123998.8		Beta◆	127/123498 CSF outbreaks on backyard premises (Pineda et al, 2020)
	Relative risk for backyard premise	RR_b	1.318 (0.616 - 2.821)		Estimated value	Backyard premise prevalence / commercial farm prevalence Proportion with 95% CI according to Morris et al 1988
	Adjusted risk for commercial farm (Reference)	$AdjRR_c$	0.805	0.782	Fixed value	R_2 /(R_1 * PrPc) + (R_2 * PrPb)
	Adjusted risk for backyard premises	$AdjRR_b$	1.062	1.031	Fixed value	AdjRRc x R_1 / R_2
	Effective probability of infection of commercial farms	EPI_{Hc}	5.96E-05	3.84E-05	Fixed value	Adjusted risk by design prevalence
	Effective probability of infection on backyard premises	EPI_{Hb}	7.86E-05	5.07E-05	Fixed value	Adjusted risk by design prevalence
ELISA test	Sensitivity of ELISA	Se Elisa	498.3; 27.2		Beta◆	National Veterinary Diagnostic Laboratory - ICA.
RT PCR test	Sensitivity of RT PCR	Se RTPCR	498.3; 27.2		Beta◆	National Veterinary Diagnostic Laboratory - ICA.
Manifestation of clinical signs	Probability of pigs on infected farm presenting clinical signs	CSi	0.65; 0.81; 0.95		Pert	Allepuz et al 2007
Variables and parameters included in the *Active surveillance on farm*						
Pig infection status (intra-herd)	Animal level prevalence (commercial)	P^*_{Ac}	550.5; 3812.6		Beta◆	268/2130 diseased over susceptible pigs on commercial farms (Pineda et al, 2020).
	Animal level prevalence (backyard)	P^*_{Ab}	999.9; 1020.2		Beta◆	2617/5291 diseased over susceptible pigs on backyard premises (Pineda et al, 2020).

Variables and parameters included in the *Passive surveillance at farm*						
Recognition of clinical signs by farmers and contact with veterinary services	Probability of commercial farmer calling the veterinary practitioner	$F_C$vet	0.80, 0.975, 1*	0.275, 0.40, 0.725*	Discrete	*25th, 50th and 75th quartiles.Quartiles obtained from a questionnaire issued to veterinary practitioners (discrete distributions in both zones included in the Supplementary Material)
	Probability of commercial farmer calling the ICA	F_CICA	0.00, 0.00, 0.05*	0.05, 0.10, 0.20*	Discrete	
	Probability of backyard farmer calling the veterinary practitioner	$F_b$vet	0.375, 0.65, 0.825*	0.187, 0.30, 0.425*	Discrete	
	Probability of backyard farmer calling the ICA	F_bICA	0.015, 0.10, 0.105*	0.015, 0.20, 0.425*	Discrete	
Veterinarian contacts ICA	Probability of veterinary practitioner calling the ICA	VetICA	0.00, 0.00, 1*	1, 1, 1*	Discrete	*25th, 50th and 75th quartiles. Quartiles obtained from a questionnaire issued to veterinary practitioners (discrete distributions in both zones included in the Supplementary Material)
Veterinarian takes samples	Probability of veterinarians performing a necropsy	VetNec	78.6; 44.2		Beta◆	ICA: 86/134 necropsy in CSF outbreaks.
	Veterinary services suspects CSF from signs and take samples	VetS$_i$S	0.00, 0.50, 0.75*	0.5, 1, 1*	Discrete	*25th, 50th and 75th quartiles. Quartiles obtained from a questionnaire issued to veterinary practitioners (discrete distributions in both zones included in the Supplementary Material)
	Veterinary services suspects CSF after necropsy and take samples	VetS$_i$NS	0.75, 1,1*	0.687, 0.875, 1*	Discrete	
Variables and parameters included in the *Passive surveillance at slaughterhouse*‡						
Farm type	Proportion of farrow-to-finish and fatteners on commercial farms	PrP$_{fatt}$	999.999, 37.233	999.999, 52.473	Beta◆	Farms database - Porkcolombia.
	Proportion of farrow-to-wean on commercial farms	PrP$_{F\text{-}W}$	975.143, 7882.703	729.903, 10625.732	Beta◆	Farms database - Porkcolombia.
Recognition of clinical signs by the slaughterhouse veterinarian	Antemortem inspection of fattener pigs	VetS$_i$AMIf	0.00, 0.225, 0.70*	0.10, 0.50, 0.762*	Discrete	*25th, 50th and 75th quartiles.Quartiles obtained from a questionnaire issued to slaughterhouse veterinarians (discrete distributions in both zones included in the Supplementary Material)
	Antemortem inspection of sows	VetS$_i$AMIs	0.20, 0.50, 1*	0.275, 0.50, 1*	Discrete	
	Postmortem inspection of fattener pigs	VetS$_i$PMIf	0.25, 0.50, 0.75*	0.437, 0.50, 0.75*	Discrete	
	Postmortem inspection of sows	VetS$_i$PMIs	0.25, 0.25, 0.50*	0.437, 0.50, 0.75*	Discrete	
Slaughterhouse veterinarian contacts ICA	Veterinarian contacts ICA after suspicions in fattener pigs	VetICAf	0.10, 0.50, 1*	0.45, 0.85, 1*	Discrete	
	Veterinarian contacts ICA after suspicions in sows	VetICAs	0.20, 0.75, 1*	0.30, 0.60, 1*	Discrete	
	ICA veterinarian takes samples	ICAS	1			ICA:Samples are taken in all CSF report
‡Only commercial farms have been taken into account at slaughterhouse ◆ All beta distributions are based on proportions with 95% CI according to clopper-pearson method (Branscum et al, 2005)						

5.3.4 Active surveillance

According to the endemic zone, small farms (backyard and family farms) have a higher risk of becoming infected than commercial farms. The relative risk (RR) of small farms compared with that of commercial ones and the proportion of both types of farm were used to calculate the adjusted risk of infection (AR) for both commercial and small farms in zones 1 and 2 (Equations 1-2).

$$AR_2 = \frac{R_2}{(R_1 * PrP_1)+(R_2 * PrP_2)} \quad \text{(Eq1)}$$

$$AR_1 = AR_2 \ * \ R_1 \qquad \text{(Eq2)}$$

Where R_1 and R_2 were the backyard premise prevalence and commercial farm prevalence and PrP_1 and PrP_2 were the proportion of backyard premises-family farms and proportion of commercial farms respectively. The sensitivity at farm level (SeHi) i.e. the probability of detecting at least one positive animal, was calculated for each of the four categories of premises (Eq 3), which was given by the within-herd prevalence for each category i (P^*_A) multiplied by the sensitivity of the two tests (Se Elisa and Se PCR) applied in series and the number of tested animals (ni) on each farm according to the 2018 and 2019 samplings.

$$SeHi = 1 - (1 - \mathrm{P}^*_A \ * \ \text{Se Elisa} * \ \text{Se PCR}\,)^{ni} \qquad \text{(Eq 3)}$$

The probability of being infected depended on the type of farm (commercial vs backyard), which was defined as the effective probability of infection (EPIH*i*) where *i* represented the type of farm and was given by the design prevalence (P^*) multiplied by the adjusted risk of each type of farm.

Finally, the sensitivity of active surveillance (Se_{active}) to detect an infected CSFV farm by serological sampling was estimated with equation 4, where *i* corresponded to the type of farm and vector *Ni* is the numer of farms sampled for each category farms. (Table 1)

$$Se_{active} = 1 - \prod_{i=1}^{4} (1 - EPIH_i \ * \ SeH_i)^{Ni} \qquad \text{(Eq 4)}$$

5.3.5 Passive surveillance

Passive surveillance was applied both on farms and at slaughterhouses. The sensitivity at farm level was evaluated on commercial and small premises, while surveillance at slaughterhouses affected only commercial farms because animals from family and backyard production are generally slaughtered in uncontrolled facilities and are not sent to slaughterhouses.
When a private or slaughterhouse veterinarian suspects CSF, he/she had to contact the ICA. A veterinary officer examined the animals in the slaughterhouse to assess the condition and if necessary, visited the farm, collected samples and sent them to the official laboratory.

Figure 2 shows the scenario tree diagram with the main elements that determine the probability of detecting a positive farm through passive surveillance. A risk node divided the farms into two branches, backyard and family farms were included in the first and all other farms were grouped as commercial farms in the second. The surveillance unit was the farm, and the same design prevalences (P) as in the active surveillance model were used.

Due to lack of information, the expert opinion was used for the estimation of parametres of some probabilities using two questionnaires addressed at farm veterinarians (18 responses), farm paraveterinarians (9 responses) and slaughterhouse veterinarians (46). The questionnaires included two different clinical cases in sows and three in fattener pigs. Very shortly, in a farm with 50 breeding sows either: a) three sows aborted and two other pregnant sows died in 2-3 days; or b) eight piglets died and 30 piglets presented anorexia and weakness. In a fattening unit with 100 pigs: a) 20% and b) 40% of fattening pigs presented anorexia, fever and dyspnea in the last 2-3 days; c) mortality was 10% of animals in the last 10 days. Veterinarians answered about the probabilities of recognition of clinical signs, of reporting or notification to the veterinarian or to the ICA, and the probability of sending samples in case of a suspicion of CSF (the questionnaire included in file annex A).

The surveillance at the slaughterhouse included only animals from commercial farms as stated above. Both fatteners and sows are sent to the slaughterhouse, so we assumed that only all farrow-to-wean farms and farrow-to-finish farms with a census ≥100 sows sent batches of sows; while farrow-to-finish farms with less than 100 sows sent fatteners and culled animals together in the same batch. As pigs were sent in batches to the slaughterhouse, the surveillance unit was the batch and it was assumed that each batch was representative of the farm of origin. The elements that determined the probabilities of detection of an infected batch during antemortem and postmortem inspections are shown in Figure 2.

The sensitivity (Sei_{farm} and $Sei_{slaught}$) corresponds to the probability of CSFV detection on a farm *i* or in a slaughterhouse batch *i* by passive surveillance.

$$Sei_{farm} = CS_i * (F_c vet\ or\ F_c ICA) * VetICA * VetS_i S * \text{Se Elisa} * \text{Se PCR} \qquad \text{(Eq 5)}$$

Where CSi was the probability of manifestation of clinical signs, Fcvet and FcICA were the probabilities of a farmer calling a veterinary practitioner or the ICA on commercial or small farms respectively, VetSiS was the probability of a veterinarian suspecting CSF and Se Elisa and Se PCR were the sensitivity of the two laboratory tests.

$$Sei_{slaught} = CS_i * (VetS_i AMI\ or\ VetS_i PMI) * VetICA_i *$$

$$ICA_s * \text{Se Elisa} * \text{Se PCR} \qquad \text{(Eq 6)}$$

Where $VetS_iAMI$ or $VetS_iPMI$ were the probabilities of recognition of clinical signs by the veterinarian in antemortem or in postmortem inspection of fatteners or sows, $VetICA_i$ was the probability of the veterinary of slaughterhouse contacting the ICA after suspicion in sows or fatterners pigs and ICAs was the probability of the ICA veterinarian taking samples.

The probability of detection of at least one infected farm by passive surveillance was given by Equations 7 and 8, where I corresponded to the total number of farms (Eq 7) and batches sent to slaughterhouse (Eq 8) under passive surveillance, EPIH*i* and EPIHc_i were the adjusted risk multiplied by design prevalence (P*) according to the type of farm (in the case of slaughterhouse only for commercial farms) and Se*i* corresponded to the probability of detection for farm *i* or slaughterhouse batch *I* (only commercial farms are included in the slaughterhouse surveillance).

$$Se_{farm} = 1 - \prod_{i=1}^{I} (1 - EPIH_i * Sei_{farm}) \qquad \text{(Eq 7)}$$

$$Se_{slaugth} = 1 - \prod_{i=1}^{I} (1 - EPIHc_i \ * \ Sei_{slaught}) \qquad \text{(Eq 8)}$$

5.3.6 Sensitivity of the whole surveillance system

We assumed that active, passive on-farm and passive at slaughterhouse surveillances were independent components, the total sensitivity of the system for the detection of one CSFV infected farm in zones 1 and 2 was calculated by the combination of the three probabilities (Eq 9) and can be defined as the probability of disease detection in at least one of the three components.

$$Se_{total} = 1 - \left[(1 - Se_{active}) * \left(1 - Se_{pas.farm}\right) * \left(1 - Se_{pas.slaughterhouse}\right)\right] \qquad \text{(Eq 9)}$$

The model was performed with R-project v3.6.3 using the library mc2d for Two-Dimensional Monte-Carlo Simulations running 5,000 iterations. This method reflected the variability in the risk and took into account the uncertainty associated with the risk estimate. The variability represented, for instance, temporal, geographical and/or individual heterogeneity of the risk for a given population. The uncertainty was understood as stemming from a lack of perfect knowledge about the Quantitative Risk Assessment model structure and associated parameters. In order to reflect the natural variability of a modeled risk, a Monte-Carlo simulation was used: the empirical distribution of the risk within the population was obtained from the mathematical combination of distributions reflecting the variability of parameters across the population. A two-dimensional (or second-order) Monte-Carlo simulation was proposed to superimpose the uncertainty in the risk estimates stemming from parameter uncertainty.(Pouillot et al., 2016, 2010).

The values obtained from the questions to veterinarians were included in the model as inputs, extracting random samples by bootstrap resampling methods from discrete distributions (a short description of discrete distributions included in the Table 2 and exact values in attached files B to E).

The sensitivity of the surveillance for the design prevalences corresponding to 5 and 10 CSFV infected farms was calculated using a bootstrap method with the results of 1,000 iterations obtained randomly from the calculations for one farm.

5.4 Results

Total sensitivity of the surveillance system was similar in both zones. The probability of detecting a single infected farm was 28-31% with a wide range (95%CI: 6-55%), and the probability of detecting infection when 5 and 10 farms were infected was 83-85% and 97-98% respectively. The passive surveillance component on farms showed the highest sensitivity for detection of a CSFV infected farm in both zones (22.8% in Zone 1 and 22.5% in Zone 2), the active surveillance and the passive surveillance at slaughterhouse presented values between 2.2 and 4.9% (Table 3).

Table 3. Sensitivity of each component and total surveillance in Zones 1 and 2 (median and in brackets 95% confidence interval).

Surveillance component	**Zone 1**			**Zone 2**		
	1 farm	**5 farms**	**10 farms**	**1 farm**	**5 farms**	**10 farms**
Active surveillance component						
Active (Design sampling 2018)	4.7 (4.2 - 5.2)	21.3 (19.4 - 23.6)	38.1 (35.1 - 41.7)	2.2 (2.1 - 2.3)	10.5 (10 - 11.1)	19.8 (19.1 - 20.9)
Active (Design sampling 2019)	4.9 (4.5 - 5.6)	22.4 (20.4 - 24.8)	39.7 (36.6 - 43.5)	3.3 (3.1 - 3.6)	15.4 (14.4 - 16.8)	28.4 (26.8 - 30.8)
Passive surveillance component *on Farms*						
Commercial	6.2 (0 - 12.7)	25 (12.1 - 37.1)	44.5 (27.5 - 55.5)	2.5 (0 - 7.4)	13.5 (5.9 - 21.9)	25.1 (15.1 - 35.2)
Backyard	17.8 (0 - 42.9)	64.4 (34.9 - 82.7)	87.5 (70.5 - 95.7)	19.4 (0 - 48.9)	70.2 (39.6 - 87.5)	91.2 (75.6 - 97.5)
Passive on farm	**23.0 (0 - 48.5)**	**73.4 (44.7 - 88.3)**	**93.1 (79.1 - 97.8)**	**21.8 (0 - 51)**	**73.9 (47.9 - 89.3)**	**93.4 (81.5 - 98.2)**
Passive surveillance component *in Slaughterhouse*						
Farrow to finish/ fattener farms	3.8 (0 - 13.5)	22.8 (7.2 - 38.7)	39.6 (18.2 - 54.8)	4.1 (0 - 7.7)	18.2 (8.5 - 26.3)	32.7 (21 - 42.7)
Farrow to wean farms*	1.2 (0 - 3.2)	6.4 (1.6 - 11.2)	12.3 (6 - 18.7)	0.4 (0 - 1)	2.2 (0.8 - 3.7)	4.5 (2.4 - 6.4)
Passive at slaughterhouse	**5.3 (0 - 15.2)**	**27.3 (11.8 - 42.6)**	**47.2 (29.9 - 62.6)**	**4.5 (0 - 8.3)**	**20.2 (10.2 - 28.5)**	**35.6 (24.6 - 45.4)**
All components						
Total	**31.4 (7.2 - 54.1)**	**85.2 (67.3 - 93.7)**	**97.9 (93.4 - 99.3)**	**27.8 (6.4 - 55.1)**	**82.5 (65 - 92.9)**	**97 (91.3 - 99.2)**

* Also includes farrow to finish farms with more than 100 sows (see text)

The sensitivity of active surveillance for the detection of CSFV infection in zone 1 was slightly more sensitive in 2019 for all scenarios compared to 2018. Instead, in zone 2, the sensitivity of active surveillance was clearly higher in 2019 vs 2018 (3.3% and 2.2 respectively for the detection of a single farm), due to the increase in the number of sampled farms (Table 3, Figure 3).

The animal level prevalence on commercial farms and the adjusted risk on commercial farms were the variables that showed the highest correlation with the obtained sensitivity of active surveillance on farms in both zones. (Spearman's rho statistic- tornado graphic included in file annex F).

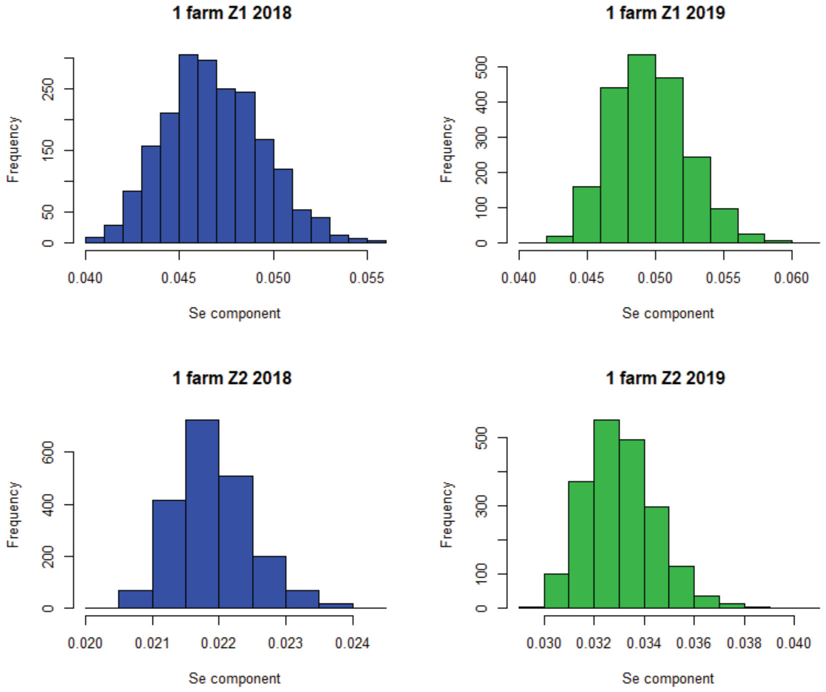

Figure 3. Distributions of the sensitivity of active surveillance in both areas for the detection of a single CSFV infected farm. Above: Zone 1, Below: Zone 2. Left: 2018 and Right: 2019.

The sensitivity of passive surveillance for the detection of one farm (commercial or family) in Zone 1 was in a range between 0 and 48.5% (CI=0.95) with a median value of 23%. For the detection of 5 farms the median value was 73.4 (44.7-88.3%). The probability of detection on a commercial farm was lower (6.2%) than on a family farm or on a backyard premise (17.8%); In Zone 2, sensitivity for the detection of a farm was similar to that observed in Zone 1 (21.8%), however, the differences between commercial and family farms was much wider (2.5% only on commercial farms and 19.4% on backyard/small farms) (Table 3 and Figure 4). The factors that showed most correlation with the efficiency of passive farm surveillance were: if the farmer called the veterinary practitioner or ICA, if veterinary services suspected CSF from signs and took samples and if veterinary services suspected CSF after necropsy and took samples. (Spearman's rho statistic- tornado graphic included in file annex G).

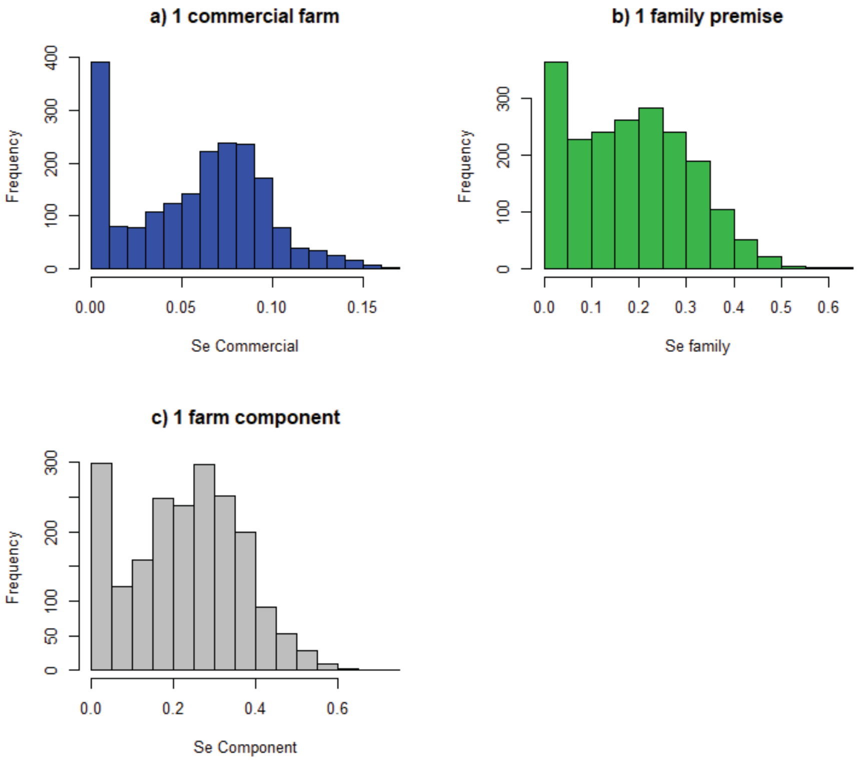

Figure 4. Distributions of the sensitivity of passive surveillance in Zone 1 for the detection of: a) one commercial farm, b) one family premise or c) any type of farm.

The passive slaughterhouse surveillance component had a sensitivity of 27.3% for the detection of five infected farms in Zone 1. It was much more sensitive to detecting the infection in fattener or in sows coming from farrow to finish farms (22.8%) than in sows (6.4%); In zone 2, the sensitivity of this component was lower (20.2%), and it showed a similar pattern for the detection of fatteners and sows (Table 3). Figure 5 shows the distribution of probabilities for a single infected farm in Zone 1.

The analysis of sensitivity of the model showed that the variables Veterinarian contacting ICA after suspicions and Veterinarian recognizing clinical signs in ante mortem and post mortem inspection had the highest correlation with passive surveillance efficiency. (Spearman's rho statistic- tornado graphic included in file annex H).

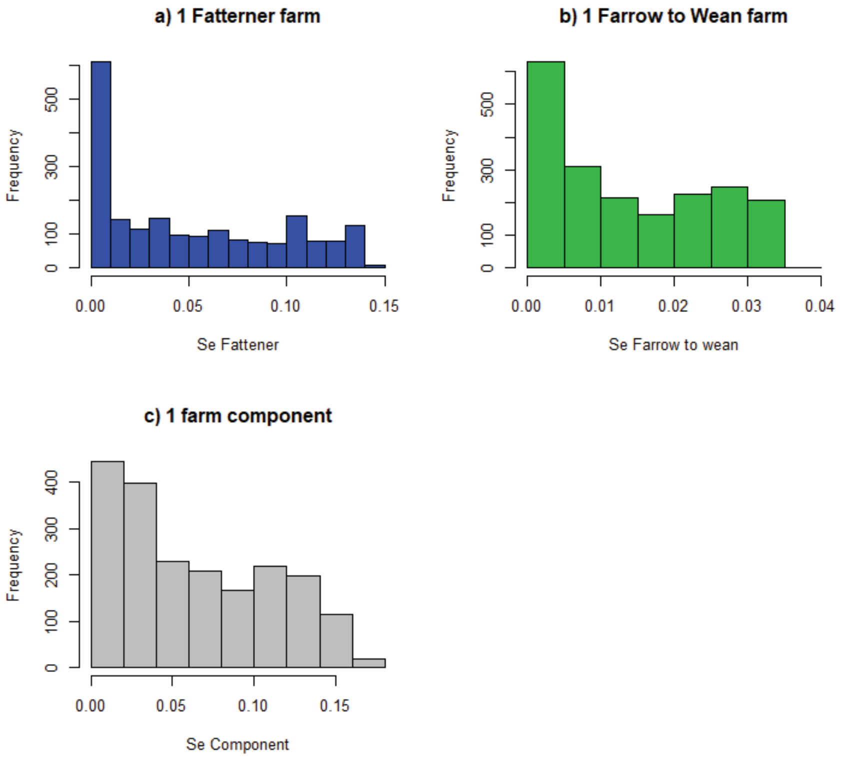

Figure 5. Distributions of passive surveillance sensitivity at slaughterhouse for the detection of one: a) farm lot Farrow to finish / fattener, b) farrow to wean or c) any type of farm in Zone 1.

5.5 Discussion

CSF was endemic in Colombia until 2007 when the disease was eradicated. In 2013, the disease was reintroduced. Until 2018, 134 outbreaks had been reported in different departments of the Atlantic Coast region, Norte de Santander and Santander of which 84% were detected by passive surveillance (Pineda et al., 2020). The endemic situation of CSF in the Atlantic Coast departments as well as in neighboring countries supposes a threat for the regions that remain free of the infection and where the animals are not vaccinated. If infection spreads in these zones, early detection of outbreaks is of paramount importance to achieve rapid and less expensive elimination of the virus on affected farms. According to our results, the sensitivity of the surveillance in the two studied zones is high. The probability of detection of a single affected farm was about 30% and the probability of disease detection when 10 premises were affected was more than 97%.

On-farm passive surveillance was by far the most sensitive component, with a median sensitivity to detect a single farm of 23%, which increased to 93% when 10 premises were infected. The sensitivity of the surveillance in the studied zones was much higher on backyard and small farms than on commercial ones, despite the capacity and predisposition to declare infections on these premises is supposed to be low (Hernández-Jover et al., 2019; Limon et al., 2014). This high sensitivity can be attributed to the Colombian strong voluntary sentinel network made up of more than 5000 members trained in diseases under official control. The network was responsible for the detection of 21 of the 134 CSF outbreaks that occurred in the endemic region (Pineda et al, 2020). This sentinel network is particularly focused on backyard premises due to their higher risk of infection and lower application of biosecurity measures. Between 2018 and 2020, 85 CSF suspicions were reported in Zone 1 and 198 in Zone 2 (ICA, 2020) which reflect good reporting in the free zones. Another reason for this high sensitivity in small farms would be that low-income farmers directly contact ICA services if their animals become diseased because they are free of cost.

On the contrary, we can assume an overestimation of the sensitivity due to bias related to backyard producers. The main reasons for this are, that only a part of them are registered in the official services while the rest probably are more reluctant to report the disease; backyard producers get used to treat the animals themselves and report only when they do not succeed (Hernández-Jover et al., 2019); and, finally, there are also farmers who do not report to avoid quarantine and restrictions (Elbers, A. R. W. et al., 2010).

Commercial farms have the advantage of having more experienced and trained farmers, veterinarians and pig handlers, however they report less. Therefore, there needs to be a strategy to encourage the reporting of suspicions, since that contact with a veterinary practitioner or ICA is one of the factors that most affect the sensitivity of passive surveillance.

Specialization of veterinarians and improving awareness of clinical signs along with pathological and virological examination for atypical signs are effective methods for the early identification of a CSF outbreak (Crauwels et al., 1999; Engel et al., 2005b). Veterinarians are considered to be a trusted stakeholder and, therefore, they can have a strong influence on the behavior of smallholders improving the willingness of disease reporting (Hayes et al., 2017; Hernández-Jover et al., 2012). Also, the relationship between producers and veterinarians play an important role in surveillance. To achieve effective passive surveillance on the part of the producer, they must trust the person receiving or providing the information. The reporting of suspected diseases by the producer could be improved by increasing their awareness of the disease seriousness, increasing the frequency and extent of animal inspections by the owners, and improving their willingness to investigate problems (Garner et al., 2016). Therefore, this is where the education and awareness programs play an important role in passive surveillance.

There is a need to maintain education and training directed at ICA staff and especially at veterinarians and other professionals working on commercial farms in order not to ignore the latent risk posed by the endemic situation on the Atlantic Coast.

Passive surveillance at slaughterhouses had a median sensitivity for the detection of a single infected farm of 5% in both Zones. It showed higher sensitivity for detecting farrow to finish or fattener farms, because of the higher volume of pigs sent to slaughterhouse compared with farrow to wean farms that occasionally send sows or boars. However, it is important to consider that in Colombia, only commercial farms send animals to slaughterhouses because most backyard premises slaughter the animals on their own facilities.

In recent years, no CSF suspicions have been reported by slaughterhouse veterinarians in Colombia, probably due to the low number of outbreaks on commercial farms and also to the low awareness of those veterinarians. The National Drug and Food Surveillance Institute (INVIMA) has a regular training and disease detection manuals for slaughterhouse veterinarians and the ICA and Porkcolombia conducts occasional training for them, but it should be reinforced in order to improve the recognition of clinical signs and lesions and knowledge about the procedure in case of a CSF suspicion.

The sensitivity of active surveillance ranged from 2.2% to 4.9% (depending on the zone and year) for detecting the infection if a single farm was infected. The differences between both zones can be attributed to the differences in the design prevalence: 1 farm supposed a higher prevalence rate in Zone 1 ($7.4\ 10^{-5}$) due to the lower number of farms compared to Zone 2 ($4.9\ 10^{-5}$).

In Colombia, active surveillance is based on the combination of the Elisa test and PCR. According to (Panyasing et al., 2018) this is the best option for effective CSFV surveillance, especially in the case of low virulence strains in order to detect both early and old infections. Other active surveillance activities carried out in the country, such as inspection at collection points, trade fairs and some premises and small farms were not considered in the study.

One of the reasons for the higher sensitivity of passive surveillance is that it is performed on a significant part of the farms in the country while only animals from commercial farms are examined at slaughterhouse and only a sample of farms is tested by active surveillance. Furthermore, passive surveillance on farms is based on the continuous monitoring of animals by farmers and veterinarians allowing the daily detection of diseased animals while the other components are evaluated only in a given period of the year when farms are monitored by active surveillance or when a batch of animals is sent to the slaughterhouse. Reporting by farmers depends on awareness that it is a serious disease (Garner et al., 2016), recognition of clinical signs (Elbers, A. R. W. et al., 2010), and trust in their veterinarian or contact personnel (Hayes et al., 2017) and also on the transparency of the reporting process to reduce the uncertainty of the farmers (Elbers, A. R. W. et al., 2010). Significant efforts have been done by the veterinary authorities and by Porkcolombia to overcome these problems.

On the other hand, the advantage of active surveillance is its ability to detect subclinical animals or animals infected with low virulent strains, in which clinical signs may go unnoticed. Consequently, all components of the surveillance system are important and complementary to detect infection in the case of an outbreak of CSF.

The stochastic scenario tree model methodology developed by Martin et al (2007) is useful not only for determining the system's efficiency but also for the identification of the components that could be improved for earlier detection of diseases.

This method can provide information about the risk of introduction of exotic disease and has the advantage of being able to use surveillance data from multiple sources (Christensen et al., 2016). It also enables evaluation of possible ways to improve sensitivity as has been described for different diseases: increasing awareness among veterinarians and farmers could improve the probability of detection of Avian Influenza in Catalonia (Spain) (Alba et al., 2010); and increasing disease awareness among salesyard and abattoir stockmen and increasing the presence of inspectors and identifying herds with a FMD higher risk can improve early detection capacity of emerging diseases in Australia (Hernández-Jover et al., 2011), while another example could be awareness among hunters, which would increase passive surveillance sensitivity for bovine tuberculosis in wildlife (Rivière et al., 2015)

This study was carried out with information from the surveillance activities applied in the country. Information related with probabilities of farmers and veterinarians suspecting CSFV infection and declaring the disease was obtained from surveys aimed at veterinarians, therefore it can reflect the current knowledge and attitudes related to CSF surveillance in the two zones. Among the limitations of this study are the parameters obtained with questionnaires (included in the supplementary material) in which some clinical cases were used as examples. Alternative cases with less or more evident clinical signs would probably have modified the responses. Also the answers were probably conditioned by the expected response rather than by their actual attitude in the case of a real situation that could go unnoticed or they might even be reluctant to report the suspicion, which may have led to an overestimation of passive surveillance sensitivity. The results present variability due to the different perception by the veterinarians and the differences between the cases included in the questionnaires. Uncertainty is also assumed in the diagnostic test due to possible differences in the results between laboratories. Therefore, the sensitivity of the farms and slaugtherhouse contains point estimates along with their credibility intervals in the dimensions of variability and uncertainty.

Other factors have been previously identified as affecting the reporting of disease outbreaks: the first is the lack of knowledge on the early signs of CSF evidenced in areas where the disease has not occurred in the last 10 years and also negative opinions regarding control measures, dissatisfaction with post-reporting procedures, lack of trust in government bodies, uncertainty and lack of transparency of reporting procedures (Elbers, A. R. W. et al., 2010). This situation may be especially common on commercial farms due to problems with the financial compensation for destroyed animals and the commercial repercussions that in many cases can lead to the definitive closure of the farm.

In conclusion, the sensitivity of the surveillance in the two studied zones was quite high, passive surveillance at farm level being higher than detection at slaughterhouse and active surveillance. Furthermore, it is important to strengthen factors that have an effect on the system's sensitivity, such as the capacity of farmers and farm and slaughterhouse veterinarians to detect clinical signs of CSF and to educate on the importance of reporting.

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Ethics statement:

This study did not need any ethical approval, most data are public and the surveys applied to veterinarians only collected their opinions, which were included in the models as probability values.

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6. DISCUSION GENERAL

La PPC es una de las enfermedades transfronterizas más importantes de los cerdos a nivel mundial y en la actualidad la más importante de las presentes en Suramérica, donde ha afectado principalmente explotaciones de traspatio, causando una elevada morbilidad y mortalidad (de Oliveira et al., 2020; Pineda et al., 2020). Además, es causa de restricciones en el comercio de cerdos vivos y productos porcinos hacia zonas o países libres de la enfermedad. Actualmente no existe un tratamiento y el control de la enfermedad en áreas endémicas se basa en la vacunación y vigilancia epidemiológica, mientras que en áreas libres las medidas se basan en sacrificio sanitario, control de movimientos, eliminación de fuentes de infección y bioseguridad.

En los 10 últimos años la producción de carne de cerdo en Colombia ha tenido un crecimiento sostenido pasando de producir 194.566 toneladas en 2010 a 468.429 en 2020. Paralelamente, los mataderos han incrementado el sacrificio de 2.5 millones a 5 millones y el consumo ha pasado de 4.8 a 10.8 Kg/habitante/año en el mismo periodo de tiempo (Porkcolombia, 2021). Esto se ha logrado por un aumento del número de granjas, pero también por el avance en el control de enfermedades transfronterizas y la mejora continua de parámetros productivos, niveles de bioseguridad y programas sanitarios en las granjas.

Colombia esta zonificada respecto a la PPC en dos zonas libres reconocidas por OIE (una de ellas reconocida por la OIE en mayo/ 2021) y zonas control con vacunación y con presencia ocasional de focos que corresponden a los departamentos fronterizos y al Norte del país. Algunas zonas reconocidas por OIE como libres de fiebre aftosa con y sin vacunación, perdieron dicho estatus por la introducción ilegal de animales vivos infectados en el departamento de Arauca (fronterizo con Venezuela) que fueron el origen de 14 brotes en 5 departamentos (Norte de Santander. Arauca, Cundinamarca, Guajira, y Boyacá) entre 2017 y 2018 pero el país recuperó posteriormente el estatus de libre (ICA, 2020). Actualmente Colombia cuenta con reconocimiento oficial por parte de la OIE de zonas libres con y sin vacunación de fiebre aftosa y de peste porcina clásica que cubren el 100% y 70% del territorio respectivamente. Este avance ha permitido abrir nuevos mercados de exportación de carne de cerdo a países como Angola, Costa de Marfil, Ghana, Hong Kong, Macao y Perú. El mantenimiento de este estatus sanitario para las enfermedades transfronterizas es uno de los principales retos para el país. Las dos principales amenazas son la existencia de países vecinos como Venezuela con un estatus sanitario indeterminado para fiebre aftosa y peste porcina clásica y la presencia ocasional de brotes de PPC en la Costa Atlántica región limítrofe a las zonas libres. Ambas situaciones suponen un riesgo latente de introducción por comercialización ilegal de animales o productos.

La Costa Atlántica es una región deprimida del país, con una producción porcina poco desarrollada, en la que el traspatio supone el 99% de las explotaciones. En las Américas, las producciones familiares de traspatio en semi confinamiento y con prácticas de manejo al aire libre han estado estrechamente relacionados con la presentación de brotes de PPC en 1997 en México y más recientemente en Brasil y Perú, (de Oliveira et al., 2020; Estrada S et al., 2001; Gómez-Vázquez et al., 2019; Terán et al., 2004). Estas explotaciones constituyen un ambiente favorable para la transmisión y mantenimiento del VPPC que dificultan la implementación de medidas de control efectivas (Terán et al., 2004).

A pesar de los esfuerzos de las autoridades en la adopción de medidas para controlar el VPPC, estas no han sido suficientes para eliminar la ocurrencia de la enfermedad en las zonas afectadas debido a varios factores: a) una proporción significativa de explotaciones de traspatio que no constan en los registros de las autoridades y que por lo tanto no están cubiertos por vacunación ni por el sistema de vigilancia, b) el sacrificio de estos cerdos sin ningún control sanitario que permita el diagnóstico de posibles casos de PPC, c) la comercialización informal de cerdos vivos en mercados abiertos con mezcla de animales de distintos orígenes y con participación de intermediarios que adquieren y mezclan animales, todas ellas son condiciones similares a las presentadas en Brasil (de Oliveira et al., 2020; Pineda et al., 2020) y d) finalmente la presencia de poblaciones de cerdos ferales o criados al aire libre que pueden mantener y diseminar el virus a poblaciones domésticas. Por lo tanto, es importante incrementar esfuerzos para registrar y vacunar a la mayoría de la población de las zonas remotas y desarrollar campañas de educación que incluyan medidas de bioseguridad básica, especialmente la relacionada con movimientos de animales y a la tenencia responsable de cerdos. Otro aspecto necesario es disponer de una infraestructura mínima de ferias y mataderos que permita el control de los movimientos animales y una inspección clínica de los mismos. Adicionalmente se deberían identificar y caracterizar los núcleos poblacionales de cerdos ferales o asilvestrados en las zonas afectadas por brotes, para desarrollar estrategias de vigilancia y control que permitan la eliminación de la circulación viral.

El impacto económico de los brotes en los últimos 8 años no fue tan elevado respecto a otros países americanos (FAO, 2003; Pinto, 2000), esto se debió en gran parte al sacrificio y compensación de solo 39 de los 156 brotes, lo que disminuyó considerablemente los costos indirectos. La vacunación preventiva fue la medida más costosa, debido a la contratación por varios años de un grupo de vacunadores para cubrir principalmente predios de traspatio y que es financiada por tasas pagadas por los productores. La ausencia de sacrificio obligatorio y compensación de animales en todos los brotes supone una de las principales fallas en la eliminación de la enfermedad, considerando que esta medida podía ser amortizada en un mediano plazo, ya que una adecuada eliminación de animales positivos y contactos conllevaría a una eliminación de la infección y a la reducción en años de la vacunación en predios.

A pesar del relativamente bajo coste económico que supusieron los brotes de peste, los productores de traspatio se vieron fuertemente afectados debido a la perdida directa de los animales y a no recibir un retorno de la inversión. Estos productores viven en zonas rurales deprimidas, con unas condiciones socio económicas de vulnerabilidad por el nivel de pobreza, y que parte de sus gastos básicos los pagan con la venta de estos animales, lo cual también se ha observado en el impacto de brotes de peste porcina africana (Chenais, Boqvist, Emanuelson, et al., 2017; Chenais, Boqvist, Sternberg-Lewerin, et al., 2017); por lo cual deberían considerarse estrategias dentro del programa con el fin de no afectar aún más sus condiciones y no desestimular su participación en los programas sanitarios.

No hay una valoración reciente del riesgo de entrada del VPPC en la zona libre, pero en un estudio del 2013, este riesgo se evaluó en la zona con vacunación de peste fronteriza con Venezuela (departamento de Arauca) donde se identificó una probabilidad de exposición de los animales al VPPC de 3.7^{-4} (IC95% 6.79^{-5} -0.00089); además en la zona con suspensión de vacunación (departamento del Meta hoy libre) se identificaron unas probabilidades de exposición de los animales y de diseminación del VPPC de 0.13 (IC95% 0.09 -0.17) y 0.03 (IC95% 0.001 -0.032) respectivamente. (Pineda et al., 2013) .

La vigilancia epidemiológica es un factor crucial en el mantenimiento del estatus de las zonas libres, en el tercer trabajo se evidenció que la sensibilidad del sistema en la detección de granjas infectadas con VPPC en las 2 zonas libres es buena, siendo la pasiva en granja más sensible respecto a la pasiva en matadero y a la vigilancia activa en granja; esta alta sensibilidad de la vigilancia pasiva se puede atribuir en parte a la amplia red de sensores voluntarios enfocados principalmente en producciones de traspatio. Sin embargo, la sensibilidad real podría ser menor, debido a que solo parte de los productores de traspatio están registrados y algunos pueden ser reacios a reportar la enfermedad. Otro punto para considerar es que las granjas comerciales son las que menos reportes realizan.

Se han identificado factores que pueden afectar la sensibilidad del sistema, como lo son que el reporte por parte de los productores depende de la concientización que es una enfermedad importante a tener en cuenta (Garner et al., 2016), el reconocimiento de signos clínicos (Elbers, A. R. W. et al., 2010), la confianza en el veterinario o personal de contacto (Hayes et al., 2017) y la transparencia del proceso de reporte para reducir la incertidumbre a los productores.(Elbers, A. R. W. et al., 2010). Por lo cual, las campañas de educación y entrenamiento regular a veterinarios y productores en el reconocimiento de signos clínicos y diagnóstico diferencial puede mejorar la eficiencia del programa de control.

7. CONCLUSIONES

1. El 94.8% de los brotes de PPC declarados entre 2013 y 2018 se han presentado en granjas de traspatio, la principal causa de transmisión fue el comercio sin control de cerdos infectados y los contactos en las ciénagas entre cerdos en semilibertad.
2. Parte de los 134 brotes se presentaron en 2 conglomerados: el primero entre 2014 y 2016 con un RR de 13.4 que afectó varios departamentos de la Costa Atlántica y el segundo con un RR de 9.6 en 2016 que incluyó municipios del departamento de Córdoba.
3. El costo de los brotes en Colombia entre 2013 y 2020 fue de 10,2 millones de dólares. La vacunación fue la medida más costosa ya que supuso el 90% del coste total, principalmente por la contratación de los vacunadores. El coste de la enfermedad para los productores afectados fue de 148.000 dólares (1,5% del coste total)
4. El costo de los brotes en Colombia fue inferior al descrito en otros países, principalmente debido a que sólo se sacrificaron animales en 37 explotaciones infectadas y en ninguna explotación contacto; esto puede haber contribuido a que no se haya conseguido erradicar la enfermedad.
5. La sensibilidad del sistema de vigilancia en las dos zonas libres para la detección de una granja infectada fue del 27.8% y el 31.4%, con unos rangos de entre el 7 y el 55% para un intervalo de confianza del 95%.
6. La vigilancia pasiva en granja demostró ser mucho más sensible (22.5% y 22.8%) que la vigilancia pasiva en matadero (4.5 y 5.3%) y la vigilancia activa en granja (2.2% y 4.5). La sensibilidad de la vigilancia pasiva se puede atribuir en parte a la amplia red de centinelas voluntarios.

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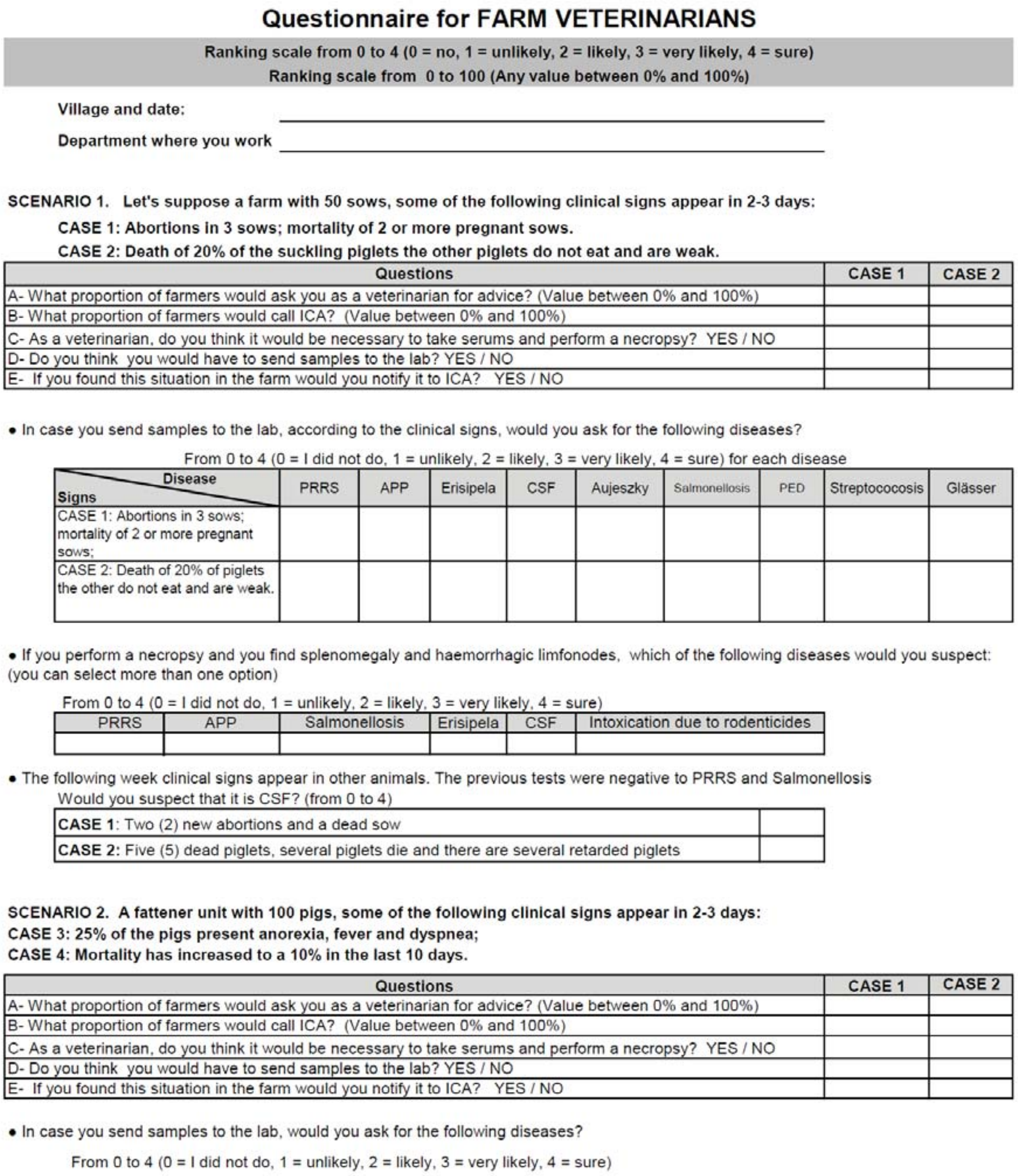
9. ANEXOS

9.1 Anexo A – Estudio III



Questionnaire for FARM VETERINARIANS

Ranking scale from 0 to 4 (0 = no, 1 = unlikely, 2 = likely, 3 = very likely, 4 = sure)
Ranking scale from 0 to 100 (Any value between 0% and 100%)

Village and date: ______________________

Department where you work ______________________

SCENARIO 1. Let's suppose a farm with 50 sows, some of the following clinical signs appear in 2-3 days:

CASE 1: Abortions in 3 sows; mortality of 2 or more pregnant sows.

CASE 2: Death of 20% of the suckling piglets the other piglets do not eat and are weak.

Questions	**CASE 1**	**CASE 2**
A- What proportion of farmers would ask you as a veterinarian for advice? (Value between 0% and 100%)		
B- What proportion of farmers would call ICA? (Value between 0% and 100%)		
C- As a veterinarian, do you think it would be necessary to take serums and perform a necropsy? YES / NO		
D- Do you think you would have to send samples to the lab? YES / NO		
E- If you found this situation in the farm would you notify it to ICA? YES / NO		

- In case you send samples to the lab, according to the clinical signs, would you ask for the following diseases?

From 0 to 4 (0 = I did not do, 1 = unlikely, 2 = likely, 3 = very likely, 4 = sure) for each disease

Disease Signs	PRRS	APP	Erisipela	CSF	Aujeszky	Salmonellosis	PED	Streptococosis	Glässer
CASE 1: Abortions in 3 sows; mortality of 2 or more pregnant sows;									
CASE 2: Death of 20% of piglets the other do not eat and are weak.									

- If you perform a necropsy and you find splenomegaly and haemorrhagic limfonodes, which of the following diseases would you suspect: (you can select more than one option)

From 0 to 4 (0 = I did not do, 1 = unlikely, 2 = likely, 3 = very likely, 4 = sure)

PRRS	APP	Salmonellosis	Erisipela	CSF	Intoxication due to rodenticides

- The following week clinical signs appear in other animals. The previous tests were negative to PRRS and Salmonellosis

Would you suspect that it is CSF? (from 0 to 4)

CASE 1: Two (2) new abortions and a dead sow	
CASE 2: Five (5) dead piglets, several piglets die and there are several retarded piglets	

SCENARIO 2. A fattener unit with 100 pigs, some of the following clinical signs appear in 2-3 days:
CASE 3: 25% of the pigs present anorexia, fever and dyspnea;
CASE 4: Mortality has increased to a 10% in the last 10 days.

Questions	**CASE 1**	**CASE 2**
A- What proportion of farmers would ask you as a veterinarian for advice? (Value between 0% and 100%)		
B- What proportion of farmers would call ICA? (Value between 0% and 100%)		
C- As a veterinarian, do you think it would be necessary to take serums and perform a necropsy? YES / NO		
D- Do you think you would have to send samples to the lab? YES / NO		
E- If you found this situation in the farm would you notify it to ICA? YES / NO		

- In case you send samples to the lab, would you ask for the following diseases?

From 0 to 4 (0 = I did not do, 1 = unlikely, 2 = likely, 3 = very likely, 4 = sure)

Disease Signs	PRRS	Circovirosis	Salmonellosis	APP	CSF
CASE 3:Anorexia, fever and dyspnea					
CASE 4: 10% Mortalily					

- In any of these cases, if you had found at necropsy hemorrhagic lesions in the torax, you would suspect one of the following diseases?

  From 0 to 4 (0 = I did not do, 1 = unlikely, 2 = likely, 3 = very likely, 4 = sure)

PRRS	Salmonellosis	APP	CSF	Intoxication due to rodenticides

- Next week other 15 animals present the same clinica signs. Animals had been PRRS and Salmollea negative

  Would you suspect that it is CSF? (from 0 to 4)

In the last 2 years you had situations similar to the exposed cases? YES / NO	
SITUATION 1: How many times did you see in farrow-to-weaning facilities?	
SITUATION 2: How many times did you see in fattener units?	

- In which type of farms did you find them?

  (If more than one, please indicate the number)

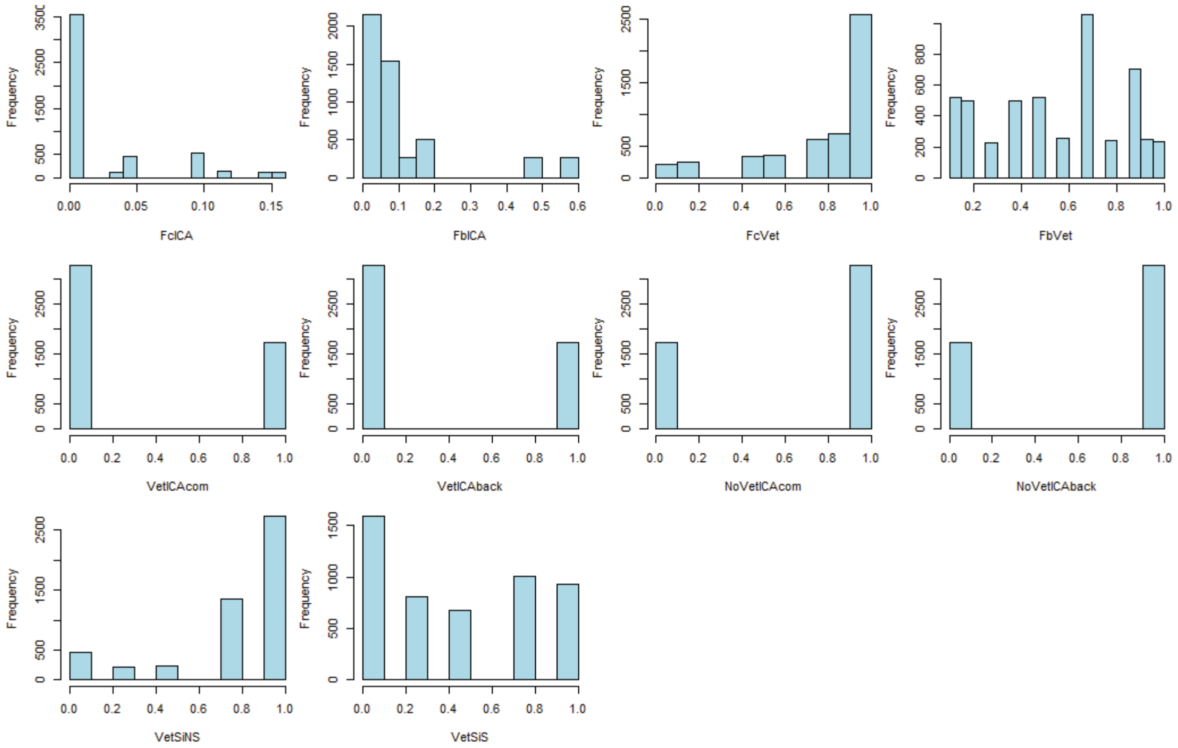
Type of farm	Number
Farrow to weaners	
Farrow to finish	
Fatteners	
Backyard	

Thank you for your collaboration

A questionnaire with similar structure was used to obtain information from the veterinarians working in slaughterhouses
It can be obtained (in Spanish) from the authors by request

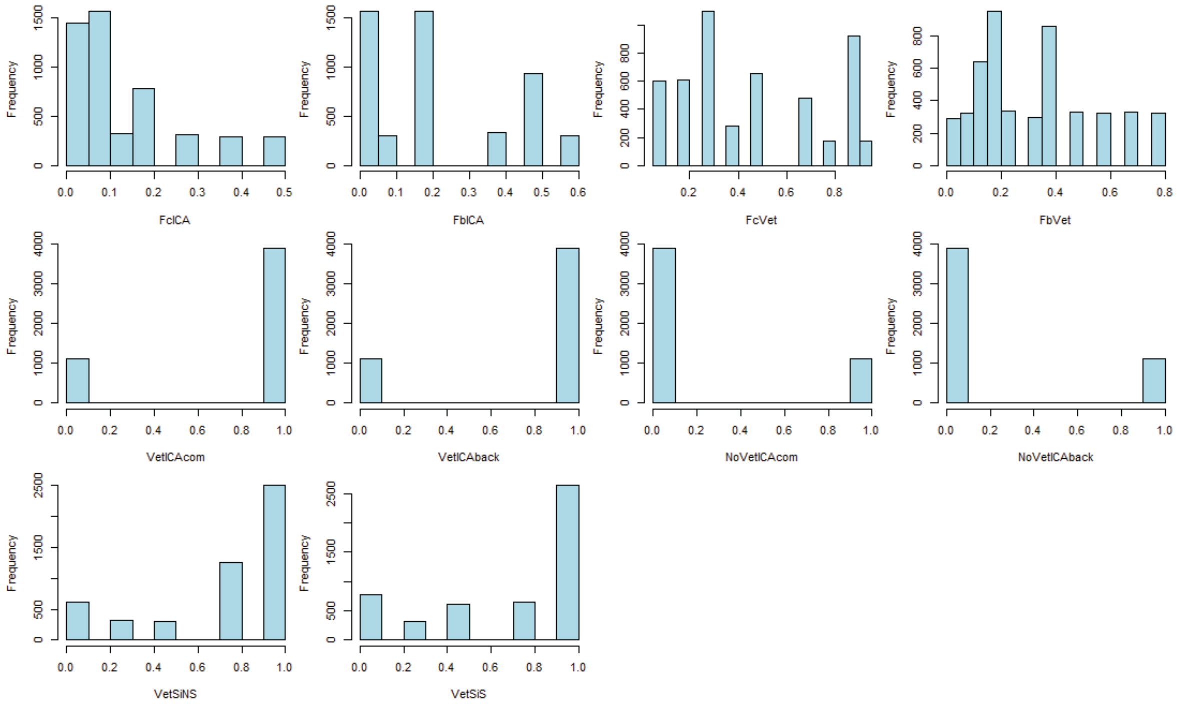
9.2 Anexo B – Estudio III

Discrete distributions from questionnaries of the veterinary practitioners in Zone 1



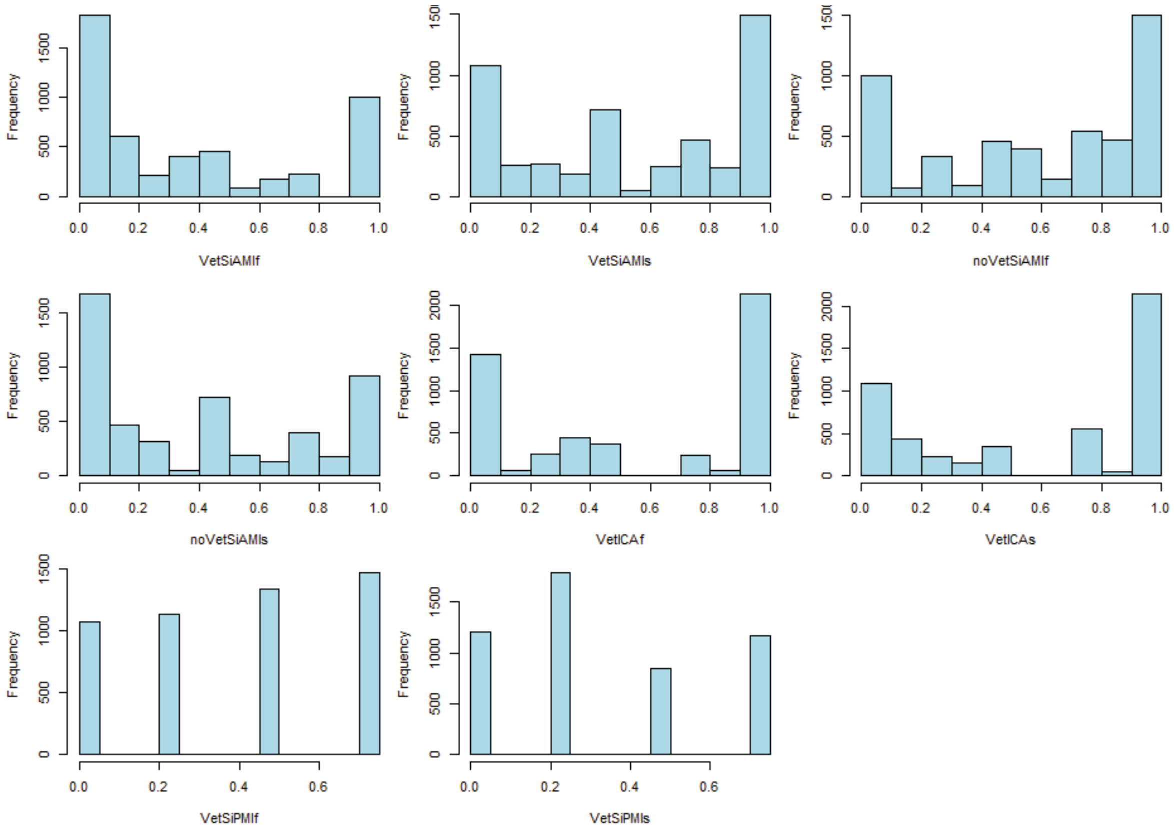
9.3 Anexo C – Estudio III

Discrete distributions from questionnaries of the veterinary practitioners in Zone 2



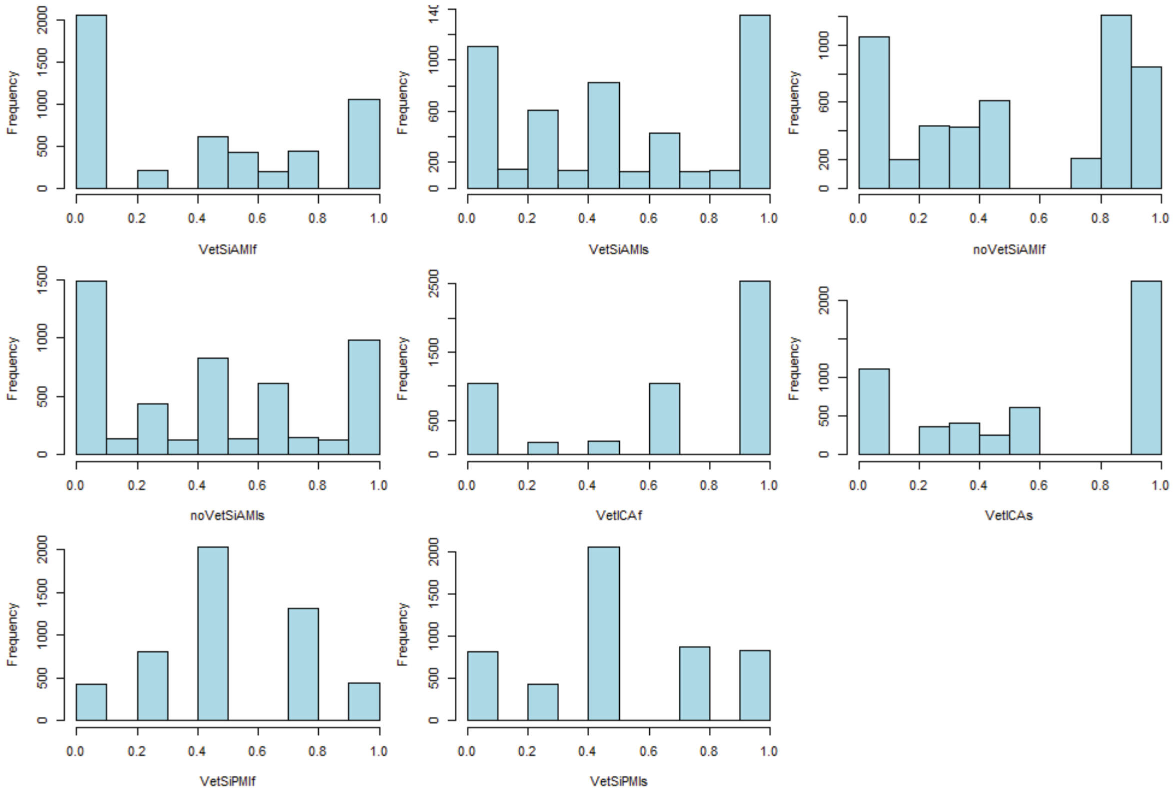
9.4 Anexo D – Estudio III

Discrete distributions from questionnaries of the slaughterhouse veterinarians in Zone 1



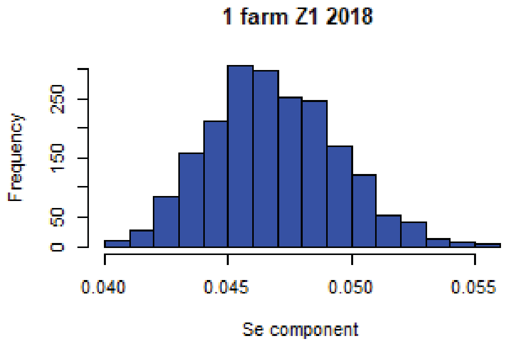
9.5 Anexo E – Estudio III

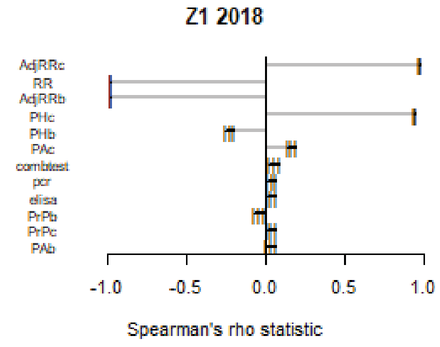
Discrete distributions from questionnaries of the slaughterhouse veterinarians in Zone 2

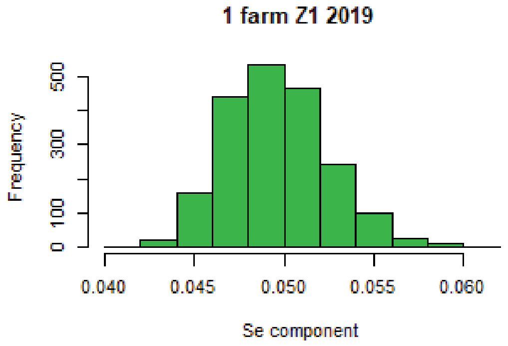


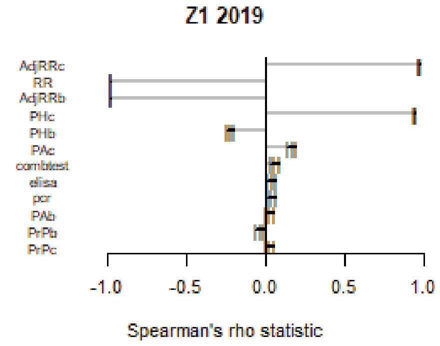
9.6 Anexo F – Estudio III

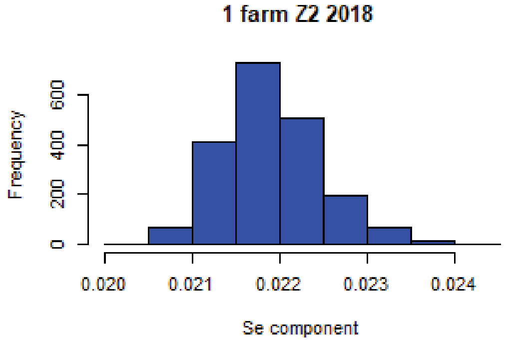
Distributions and tornado graphic of the active surveillance in Zone 1 and Zone 2

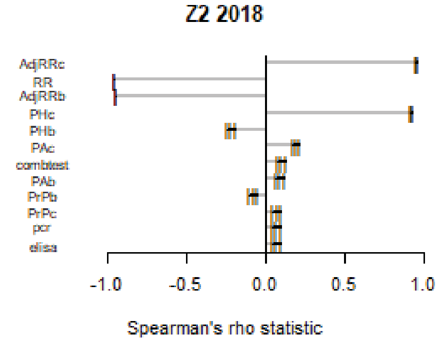

1 farm Z1 2018

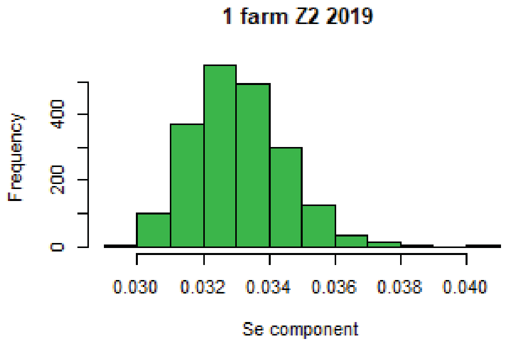

Z1 2018

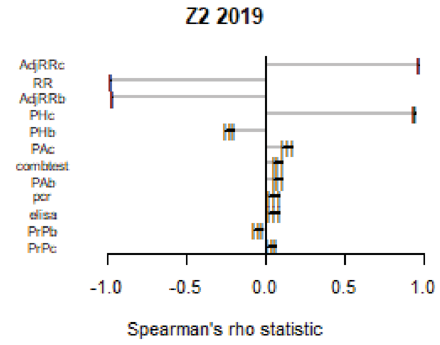

1 farm Z1 2019


Z1 2019


1 farm Z2 2018

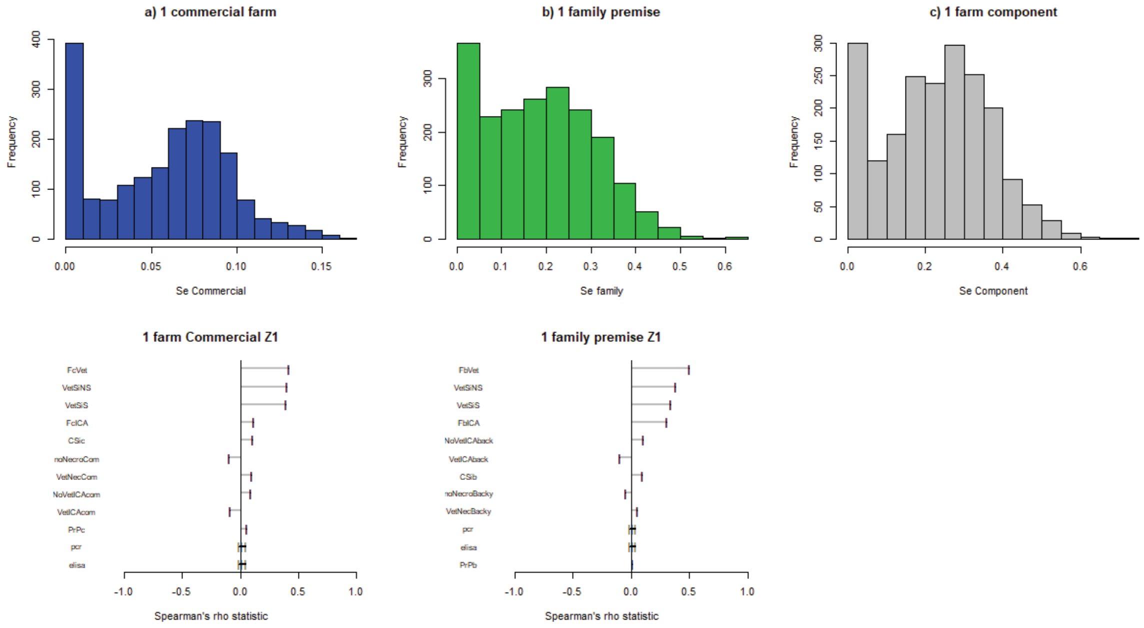

Z2 2018


1 farm Z2 2019


Z2 2019

9.7 Anexo G – Estudio III

Distributions and tornado graphic of the passive surveillance in farms in Zone 1



9.8 Anexo H – Estudio III

Distributions and tornado graphic of the passive surveillance at slaughterhouses in Zone 1