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African swine fever outbreak in Camiguin Island, Philippines: An analysis of biosecurity and control strategies

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ABSTRACT

African Swine Fever (ASF) is a highly contagious and deadly disease that threatens swine populations and rural livelihoods. In Camiguin, Philippines, the first case was confirmed on July 2, 2022, leading to strict movement controls and biosecurity measures. This study analyzed the distribution, severity, and impact of ASF across the province's five municipalities namely; Mambajao, Sagay, Mahinog, Catarman, and Guinsiliban while identifying likely infection sources and evaluating local control strategies.Using a descriptive research design, data were collected from Municipal Agriculture Officers and Agricultural Technicians through validated questionnaires covering pig losses, infection sources, and interventions. Both descriptive statistics and Chi-square tests were applied for the analysis of the data. Findings showed uneven ASF distribution. Mambajao and Sagay were most affected, with 100% of barangays impacted. Mahinog had moderate spread (76.92%), while Catarman and Guinsiliban experienced more localized outbreaks (28.57% and 33.33%). Statistical analysis confirmed significant differences in distribution ($p < 0.05$), suggesting local factors such as swine density, pork movement, and farm biosecurity. Mambajao was identified as the epicenter, with over 500 pigs affected. Major infection sources included swill feeding and contaminated pork movement (27.8%), poor biosecurity (21.1%), and slaughter of infected pigs (17.8%). Minor factors included personnel, environmental, and vehicle transmission. Control strategies varied significantly. While biosecurity was widely practiced, quarantine, isolation, and wild pig avoidance were inconsistently applied. A significant association between municipality and strategy adoption ($p = 0.002$) reflected differences in resources and awareness. Overall, effective ASF control requires localized, resource-sensitive strategies combining strict biosecurity, community engagement, and targeted support.

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INTRODUCTION

The island province of Camiguin, renowned for its scenic beauty and natural attractions across its five municipalities (Mambajao, Catarman, Sagay, Guinsiliban, and Mahinog), was severely impacted when the Department of Agriculture Regional Field Office 10 confirmed its first African Swine Fever (ASF) case on July 2, 2022, following laboratory diagnosis of infected pig samples from Barangay Pandan, Mambajao (Philippine News Agency, 2022; Manila Bulletin, 2022). The announcement triggered panic among swine raisers across the province, both small and large scale, due to the disease's high contagion and fatality. In response, the provincial government-imposed bans on hog movements, restricted pork entry, and enforced strict biosecurity protocols, even as the most vulnerable backyard raisers, largely from poor to middle-income households, bore the brunt of the economic burden (Philippine News Agency, 2022).

African Swine Fever is a highly contagious viral disease with mortality rates reaching nearly 100%, posing a major threat to both domestic and wild pig populations globally and resulting in dire economic consequences for the pork sector (World Organization for Animal Health-WOAH, 2024; Mulumba *et al.*, 2023). Beyond the immediate production losses, ASF outbreaks cause severe socioeconomic impacts, particularly for rural households dependent on pigs for livelihood and food security (Fasina *et al.*, 2012; Costard *et al.*, 2013). Transmission is facilitated through contact with infected bodily fluids, consumption of contaminated pork products, and improper disposal of carcasses, with smallholder settings especially vulnerable due to limited biosecurity (Penrith and Vosloo, 2019; Quembo *et al.*, 2023).

In the Philippines, ASF was first reported in July 2019 in backyard farms in Rizal and Bulacan provinces, spreading rapidly across Luzon and later reaching the Visayas and Mindanao (Department of Agriculture, 2019; Balibago *et al.*, 2023). By 2020, ASF had caused massive culling of pigs and disrupted the pork supply chain, with estimates of more than 3 million pigs lost nationwide due to mortality and depopulation (Food and Agriculture Organization, 2021). The outbreaks devastated smallholder farmers, who comprise the majority of the country's swine raisers, leading to livelihood losses and contributing to pork price surges. While the government and local authorities implemented movement bans, quarantine checkpoints, and biosecurity campaigns, ASF remains a recurring threat, with sporadic outbreaks still being reported in different regions (Rappler, 2022).

In Camiguin, following the confirmation of ASF-positive cases by the Department of Agriculture Regional Animal Disease Diagnostic Laboratory in several barangays of Mambajao, provincial authorities promptly implemented strict control measures, which successfully prevented further reported outbreaks (Philippine News Agency, 2022; Rappler, 2022). Although ASF has been widely studied in other provinces and countries, localized research on its epidemiological patterns and socioeconomic implications in Camiguin remains scant. This gap underscores the need for a context-specific assessment that examines the disease's distribution, transmission pathways, and effectiveness of implemented prevention and control strategies (Quembo *et al.*, 2023; Balibago *et al.*, 2023). In line with this, the present study was conducted to determine the distribution, intensity and impact of ASF cases across the municipalities of Camiguin, identify probable sources of infection, and assess the prevention and control strategies implemented by local authorities.

MATERIALS AND METHODS

Study area

This study aimed to examine the distribution of African Swine Fever (ASF) cases its intensity and impact, identify probable sources of infection, and assess the effectiveness of prevention and control strategies across the municipalities of Camiguin. It employed a descriptive research design and was carried out from May to December 2024 in

partnership with the Provincial Veterinary Office. The setting was the island province of Camiguin (Fig. 1), located north of Cagayan de Oro City and bounded by the Bohol Sea, Macajalar Bay, Gingoog Bay, and Butuan Bay. Despite its small land area of approximately 90 square kilometers, Camiguin comprises five municipalities namely; Mambajao (the capital), Catarman, Sagay, Guinsiliban, and Mahinog and is recognized as one of the smallest island in the Philippines (PSA, 2020; DOT, 2023).

Fig. 1. Camiguin Island, Philippines, served as the research site for the analysis of African Swine Fever (ASF) distribution across its five municipalities: Mambajao, Mahinog, Sagay, Guinsiliban, and Catarman

Participants and materials

The respondents of the study were Municipal Agriculture Officers and Agricultural Technicians from the five municipalities, who served as key informants because of their direct engagement in swine health monitoring and outbreak response. Data were gathered using a structured questionnaire that was validated by three subject-matter experts prior to its administration. The questionnaire was designed to capture essential information on the distribution of ASF cases, the intensity and impact of outbreaks, the probable sources of infection, and the prevention and control strategies implemented across Camiguin.

Procedure for data collection

Prior to data collection, formal permission was secured from the Provincial Governor, Municipal Mayors, and Municipal Agriculture Offices to ensure compliance with local governance protocols. Upon approval, the research team coordinated directly with the five Municipal Agriculture Offices in Camiguin. Municipal Agriculture Officers (MAOs) and Agricultural Technicians being frontline implementers of livestock health programs and ASF response activities were identified as key informants and invited to participate in the study.

A Structured and face-to-face interview were conducted using the validated questionnaire to gather detailed accounts of ASF outbreaks, sources of infection, and the prevention and control measures adopted in their respective municipalities. Respondents were asked to provide information based on their technical reports, field experiences, and direct observations of swine raisers during the outbreak. All responses were carefully recorded, cross-checked with available municipal records when possible, and systematically documented to ensure consistency and reliability for subsequent analysis.

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics such as frequency counts, percentage distributions, and rankings were applied to summarize quantitative and qualitative findings. Inferential statistics were employed to test relationships, Chi-square Test of Independence was used to compare the distribution of ASF-affected barangays and the implementation of control strategies across municipalities, while the Chi-square Goodness-of-Fit Test assessed whether reported sources of infection occurred equally across the province.

RESULTS AND DISCUSSION

Distribution of African swine fever-affected Barangays per municipaly in Camiguin

The distribution of ASF cases varied across the five municipalities of Camiguin (Fig. 2). Mambajao and Sagay reported the highest impact, with all of their barangays (100%) affected by the outbreak. In Mahinog, 10 out of 13 barangays (76.92%) were affected, indicating a moderately widespread occurrence. In contrast, the outbreak was more localized in Catarman and Guinsiliban, with only 28.57% and 33.33% of their barangays affected, respectively. This uneven distribution highlights differences in exposure risks, farm practices, and effectiveness of biosecurity measures across municipalities. The results revealed a statistically significant difference in ASF distribution across municipalities ($p < 0.001$). This suggests that the spread of ASF was not uniform but influenced by contextual factors such as swine population density, movement of pork products, and varying levels of farm-level biosecurity compliance.

Municipalities with higher swine populations and greater inter-barangay movement of live pigs and pork products, such as Mambajao, were more vulnerable to rapid disease transmission.

The results revealed that ASF was unevenly distributed across municipalities, with Mambajao and Sagay showing 100% of barangays affected, while Catarman and Guinsiliban reported less than 35%. This heterogeneity suggests that ASF transmission was strongly shaped by local factors such as swine population density, trading activity, and levels of biosecurity enforcement. Similar trends have been documented in other parts of the Philippines, where ASF spread followed pig movement and marketing channels rather than mere geographic proximity (Balibago *et al.*, 2023). International studies also confirm that outbreaks tend to cluster in areas with dense pig populations and active trading, underscoring the role of human-mediated transmission (Costard *et al.*, 2013; Sánchez-Vizcaíno *et al.*, 2015).

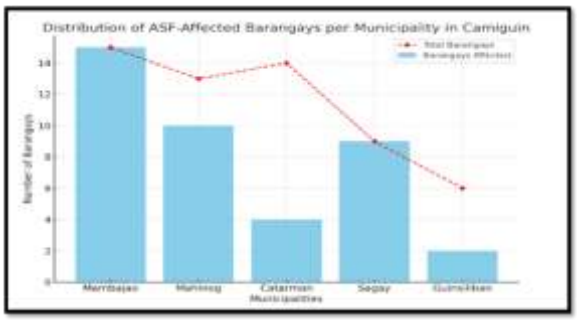

Fig. 2. Distribution of ASF affected barangays per municipality, an association between municipality and ASF barangays status

The significant statistical difference in ASF distribution ($p < 0.001$) reinforces the need for municipality-specific interventions. As Penrith and Vosloo (2019) emphasized, "one-size-fits-all" strategies are often ineffective in smallholder-dominated systems; instead, responses must be tailored to local risk dynamics. This heterogeneity reflects key epidemiological patterns. The ASF transmission is strongly influenced by local pig population density, trade and movement of pigs/pork products, and farm-level biosecurity compliance (Costard *et al.*, 2013; Sánchez-Vizcaíno *et al.*, 2015; Balibago *et al.*, 2023). Municipalities with high connectivity, such as Mambajao, are particularly vulnerable to rapid spread and high losses, whereas limited exposure or early containment likely explains the smaller impact in Catarman and Guinsiliban (Penrith and Vosloo, 2019).

The distribution also implies human-mediated transmission is central. Swill feeding, movement of infected meat, and inadequate biosecurity dominate as probable sources of infection, consistent with previous studies on backyard systems in the Philippines and globally (FAO, 2020; Cadenas *et al.*, 2022; Quembo *et al.*, 2023). Low compliance with quarantine and isolation measures in some municipalities further exacerbates spread, underscoring the need for integrated interventions that combine practical biosecurity, movement controls, and community engagement (Bellini *et al.*, 2016; Liu *et al.*, 2021). By contextualizing ASF within Camiguin's smallholder systems, this analysis provides evidence-based guidance for tailored, municipality-specific interventions, emphasizing biosecurity, community participation, and socioeconomic support to prevent future outbreaks.

Intensity and impact of ASF per municipality in Camiguin Island, Philippines

The data show that the intensity and impact of ASF (African swine fever) varies significantly across the five municipalities in Camiguin Island, Philippines as visualized in Fig. 3. The data reveals a significant geographic spread, with Mambajao emerging as the epicenter of the outbreak and categorized as medium in severity. This intensity underscores its position as the hardest-hit area. Mambajao experienced the most severe outbreak, classified as medium impact with more than 500 pigs affected and importantly, all 15 barangays were affected (100%), indicating widespread transmission and high vulnerability. Sagay also shows a full spread across barangays, as all 9 barangays were affected (100%), but the number of pigs affected was relatively low. This suggests that while the geographic spread was complete, the scale of loss per barangay was small, possibly due to fewer backyard pig raisers or smaller herd sizes. Mahinog had moderate spread, with 10 out of 13 barangays (76.92%) affected, but with limited pig losses. This indicates broader coverage than Catarman and Guinsiliban, but still less extensive than Mambajao and Sagay. Catarman reported ASF cases in only 4 out of 14 barangays (28.67%), showing that the spread was contained in certain localities, although pig losses remained under 100. Guinsiliban had the least impact, with only 2 of 6 barangays (33.33%) affected and pig losses below 100, highlighting a localized and relatively contained outbreak. These differences highlight the role of swine density, biosecurity practices, and local governance in shaping the extent of ASF transmission. The findings suggest that while ASF spread rapidly in municipalities with higher pig populations and active trading, smaller and less connected areas experienced more limited outbreaks.

Fig. 3. Heatmap illustrating the spatial distribution and intensity of African Swine Fever (ASF) cases across affected barangays in Camiguin Island, Philippines

Further, the spatial distribution of ASF cases, as shown in the heatmap, demonstrates a clustered pattern of infection, with Mambajao emerging as the most critical hotspot, indicated by areas of high-intensity red coloration. This suggests that the municipality experienced a significant level of ASF transmission, likely due to higher pig population density and greater inter-barangay movements of swine. On the other hand, Mahinog and Catarman displayed relatively lower outbreak intensities, reflected by the blue zones, indicating that fewer barangays were affected in these areas. The observed clustering supports the epidemiological trend that ASF spreads more rapidly in areas with dense swine production and limited biosecurity measures (Costard *et al.*, 2013; Penrith *et al.*, 2019). Furthermore, the geographical spread of ASF across multiple municipalities suggests possible gaps in quarantine enforcement and inter-barangay biosecurity

protocols, which have been identified as risk factors in ASF transmission in the Philippines (Bureau of Animal Industry, 2021).

Overall, the heatmap indicates that ASF outbreaks in Camiguin are not evenly distributed but rather localized in specific hotspots. This calls for targeted interventions, such as stricter movement control, enhanced community-based surveillance, and focused biosecurity training in high-risk municipalities, particularly in Mambajao and its surrounding barangays.

Probable sources of ASF infection in the different municipalities

The study identified multiple probable sources of ASF infection across the municipalities of Camiguin (Fig. 4). The most frequently cited source was the movement of infected meat through swill feeding or contaminated food (n= 25, 27.8%), followed by inadequate biosecurity protocols (n= 19, 21.1%) and slaughtering of infected pigs (n= 16, 17.8%).

Other notable sources included ingestion of infected meat products (n= 17, 18.9%), movement of personnel (n= 9, 10.0%), and environmental contamination (n= 9, 10.0%).

Less frequently reported sources were boar for hire (n= 7, 7.8%), contaminated vehicles (n= 6, 6.7%), introduction of new pigs (n= 5, 5.6%), and dogs (n= 2, 2.2%).

Swill feeding and the movement of contaminated meat emerged as the most frequent sources of infection, followed by inadequate biosecurity and the slaughter of infected pigs. These findings mirror global evidence: swill feeding remains the single most critical risk factor for ASF introduction, particularly in backyard systems (FAO, 2020; Cadenas-Fernández *et al.*, 2022). Weak or inconsistent biosecurity measures, such as poor disinfection and lack of quarantine, have similarly been shown to facilitate ASF persistence and spread (Brown and Bevins, 2018; Penrith *et al.*, 2019).

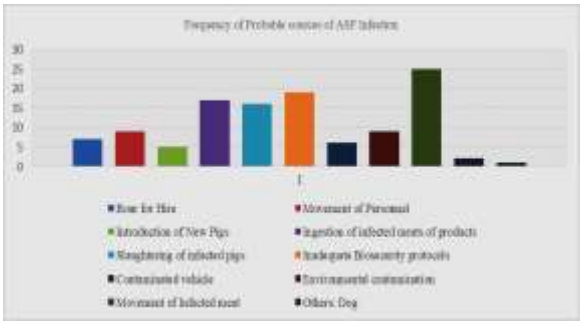

Fig. 4. The frequency of the probable sources of African swine fever infection across of the municipalities of Camiguin

Furthermore, the slaughter and sale of infected pigs not only heightens direct viral transmission but also perpetuates the circulation of contaminated pork products, as seen in other outbreak contexts (Reyes *et al.*, 2023). Personnel movement, vehicles, and environmental contamination were identified as minor but notable contributors, consistent with studies confirming that ASF can spread via fomites and human activities (Juszkiewicz *et al.*, 2023). These results underscore the multifactorial nature of ASF epidemiology and the necessity of addressing risks beyond direct pig-to-pig transmission.

Frequency of ASF prevention/control strategies by municipality

A summary of African Swine Fever (ASF) prevention and control strategies implemented across five municipalities is presented in the Fig. 5. Biosecurity measures (e.g., footbaths, restricted farm access) were the most consistently applied, with all municipalities (100%) adopting them. Disinfection of facilities was also widely practiced, whereas strategies such as quarantine of newly introduced pigs, isolation of sick animals, and avoidance of contact with wild pigs were less frequently implemented. Statistical analysis revealed significant differences in the implementation of ASF prevention and control strategies across municipalities. Specifically, there was a statistically significant association between municipality and strategy implementation ($p < 0.05$). This finding suggests that some municipalities were more proactive in adopting certain control measures than others. The uneven distribution of strategies across

municipalities may reflect variations in resources, biosecurity awareness, or the severity of ASF outbreaks.

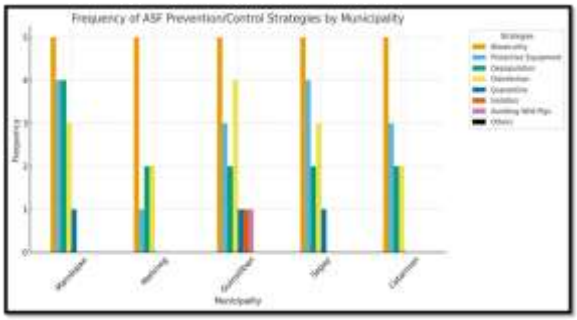

Fig. 5. The clustered bar chart of ASF prevention and control strategies implemented across five municipalities of Camiguin Island, Philippines

The results of the study revealed notable variations in the implementation of African Swine Fever (ASF) prevention and control strategies across the five municipalities. Biosecurity measures, including the use of footbaths and restricted farm access, were universally practiced, reflecting their recognition as a frontline defense against ASF (Costard *et al.*, 2013; Penrith and Vosloo, 2019). Disinfection of facilities was also commonly adopted, highlighting farmers' awareness of its role in reducing viral persistence in the environment (Mazur-Panasiuk *et al.*, 2019). In contrast, more targeted interventions—such as quarantine of newly introduced pigs, isolation of sick animals, and avoidance of contact with wild pigs were applied in only a minority of municipalities. This suggests gaps in farmers' knowledge, limited resources, or challenges in enforcing these measures at the community level (Chenais *et al.*, 2019). These findings reflect broader challenges in ASF management: while preventive measures such as footbaths are relatively simple and inexpensive to enforce, resource-intensive practices like isolation of sick pigs require greater farmer capacity and sustained government support (Bellini *et al.*, 2016). The statistical analysis confirmed significant differences in the adoption of strategies across municipalities ($p < 0.05$), indicating that local context such as resource availability, awareness campaigns, and outbreak severity likely influenced the degree of compliance with ASF control practices.

Overall, the uneven distribution of ASF prevention strategies demonstrates that some municipalities were more proactive than others. Similar patterns have been documented in other ASF-affected areas, where inconsistent implementation of control measures often undermines eradication efforts (Dione *et al.*, 2016). These findings emphasize the importance of strengthened information dissemination, targeted training, and resource support to ensure more uniform and comprehensive implementation of ASF biosecurity strategies across municipalities. Overall, this study highlights that ASF in Camiguin followed transmission pathways similar to those documented elsewhere, but its distribution and control varied significantly across municipalities. Effective prevention requires tailored, community-based interventions that emphasize swill feeding elimination, strict but feasible biosecurity, and consistent implementation of quarantine and isolation. These findings reaffirm that ASF cannot be managed solely through top-down approaches; farmer participation, government support, and socioeconomic assistance are indispensable for sustainable control (FAO 2021; Penrith and Vosloo, 2019).

The preventive and control strategies findings underscore the critical role of biosecurity measures in mitigating the spread of African Swine Fever (ASF). Universal adoption of biosecurity protocols, such as footbaths and restricted farm access, aligns with established recommendations emphasizing their efficacy in preventing ASF transmission (Liu *et al.*, 2021). Disinfection procedures, another widely implemented strategy, are essential in reducing environmental contamination and virus persistence (Juszkiewicz *et al.*, 2023).

However, the inconsistent application of other measures like quarantine and isolation may reflect challenges in resource allocation and enforcement, as noted in previous studies (Bellini *et al.*, 2016).

The significant variability in strategy implementation across municipalities, as indicated by the chi-square test, suggests that local factors such as governance, infrastructure, and farmer awareness play pivotal

roles in ASF control efforts. This variability is consistent with findings by Alarcón *et al.* (2021), who highlighted the influence of local conditions on biosecurity practices. While biosecurity and disinfection are foundational to ASF prevention, a multifaceted approach addressing local challenges and enhancing strategy implementation is essential for effective disease control.

CONCLUSION

This study found that African Swine Fever (ASF) in Camiguin was unevenly distributed, with Mambajao and Sagay most affected and Catarman and Guinsiliban least affected. Outbreak dynamics were strongly associated with swine density, pork movement, and biosecurity compliance, with swill feeding, contaminated meat movement, and weak biosecurity identified as key drivers of transmission. Although biosecurity measures were in place, inconsistent implementation of quarantine and isolation highlighted gaps in outbreak control.

As the first systematic assessment of ASF in Camiguin, the study demonstrates that control efforts should be municipality-specific rather than uniform, emphasizing the need for farmer participation, socioeconomic support, and localized strategies within smallholder production systems. Overall, the findings provide context-specific evidence from an island setting and support integrating epidemiological and socioeconomic approaches in disease management.

Effective ASF control in Camiguin therefore requires strict biosecurity enforcement, sustained prohibition of swill feeding, and continued support for backyard raisers, with implications for similar smallholder and island contexts.

RECOMMENDATIONS

This study recommends strengthening and standardizing biosecurity implementation across all municipalities in Camiguin through regular monitoring and strict enforcement of quarantine, isolation, and sanitation protocols. Continued strict enforcement of the swill feeding ban is essential, supported by access to affordable and safe alternative feeds for backyard raisers. Regulation of pig and pork movement should also be enhanced through improved documentation, checkpoint monitoring, and the development of a simple community-based traceability system to reduce inter-municipality transmission. ASF interventions should be localized and risk-based, with intensified surveillance and stricter control measures in high-incidence areas such as Mambajao and Sagay. In addition, sustained farmer education and community engagement are necessary to improve awareness, early detection, and reporting of cases, alongside strengthened coordination among barangay, municipal, and provincial veterinary offices for faster response. Finally, socioeconomic support for affected backyard raisers should be expanded to reduce financial vulnerability, discourage risky practices, and promote recovery under strict biosecurity conditions.and sustainable repopulation under strict biosecurity conditions.

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