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# Prevalence and Risk Ranking of Meat-Borne Parasites of One Health importance in the Zimbabwean Meat Industry

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# Abstract

Foodborne parasites cause significant morbidity and mortality worldwide, with developing countries disproportionately affected due to inadequate sanitation and health infrastructure. In Low- and Middle-Income Countries (LMICs), where human and financial resources are limited, risk ranking of parasitic food safety hazards is essential to guide national authorities in prioritising those posing the greatest public health burden.

This study ranked One Health-relevant parasites by public health importance and mapped their prevalence nationally and across provinces in Zimbabwe. Twenty-three experts from veterinary medicine, livestock production, and meat hygiene were recruited through professional networks to participate in a structured, three-round Delphi process. Prevalence data were obtained from the National Veterinary Authority database. A Multi-Criteria Decision Analysis (MCDA) framework was applied.

Four parasites were ranked in descending order of national public health priority: *Taenia saginata* (rank 1), *Taenia solium* (rank 2), *Echinococcus granulosus* (rank 3), and *Fasciola* spp. (rank 4), with corresponding prevalences of 1.10%, 0.08%, 0.53%, and 0.64%, respectively. National rankings were largely consistent across provinces, though disparities in a few regions reflected divergent local epidemiological conditions.

Risk ranking exercises of this nature serve a foundational role in food safety governance. By systematically prioritising hazards according to their public health significance, they enable regulatory authorities to establish evidence-based meat inspection priorities, allocate resources efficiently, and assess whether existing policy frameworks are proportionate to the burden posed by individual hazards.


# Introduction

Foodborne parasites cause illness and death in millions of people worldwide [1]. In addition, parasites impose considerable strain on economies and healthcare systems, particularly in low- to middle-income countries (LMICs) [2]. Globally, the World Health Organisation (WHO) estimated that foodborne parasites accounted for over 23 million recorded foodborne illness cases, 45,000 deaths, and a cumulative 8 million disability-adjusted life years (DALYs) over a five-year period [2]. In Africa, the WHO estimates that 1.5 million people suffer from illnesses induced by foodborne parasites, with about 17,000 deaths annually [3]. Poor countries bear a disproportionate share of the foodborne parasite disease-burden owing to inadequate food safety infrastructure and under-resourced healthcare systems [2]. Global health authorities have categorised several of these diseases as ‘neglected’ [4], underscoreing the insufficient attention devoted to these conditions.

Meat is a predominant vehicle for the transmission of serious foodborne parasites [5]. In an exercise to rank the importance of foodborne parasites globally, the WHO placed *Taenia solium*, a meat-borne parasite first ,in a list of more than twenty hazards spread by other foods [1]. Animal flesh can harbour the developmental stages of parasites and, as such, perpetuate their life cycles across humans, the

environment, and other animals [5]. Humans are infected primarily through the ingestion of undercooked, parasite-infested meat, subsequently spreading infection to other humans or animals through the excretion of parasite eggs [5]. Various parasites from the kingdoms Animalia and Protista are significant in the transmission of disease through meat. Among those with global documentation are species from the genera *Taenia*, *Echinococcus*, *Fasciola*, *Trichinella*, *Diphyllobothrium*, and *Toxoplasma* [1].

Risk mapping is an acceptable means for resource-poor countries to assess the risk of foodborne parasites [6]. Globally, the WHO [1] has applied Multi-Criteria Decision Analyses (MCDA) to rank foodborne parasites, with the same approach used in national exercises [6]. Zimbabwe, like other LMICs, requires systematic risk ranking of food safety hazards to effectively allocate limited public health management resources. A meat-borne parasite-specific risk ranking would inform the conduct of inspection and monitoring activities and support the evaluation of existing food safety policies.

## Materials and Methods

# Study Design

This study employed a cross-sectional design to determine the prevalence of meat-borne parasites of One Health importance across all provinces of Zimbabwe from January to December 2024 and to rank them according to their risk to public health. Prevalence data (for the year 2024) were extracted from a national veterinary database, and risk ranking was conducted through an expert-driven, multi-criteria methodology.

## Study Area

Zimbabwe is a landlocked country in southern Africa with a population of 15.1 million, according to the 2022 national census [7]. The country's economy is predominantly agrarian, with most of its population residing in rural areas [8]. Administratively, Zimbabwe is divided into ten provinces: Harare, Bulawayo, Manicaland, Mashonaland Central, Mashonaland East, Mashonaland West, Matabeleland North, Matabeleland South, Masvingo, and Midlands [7], as depicted in Fig. 1. The country's livestock sector is substantial; as of the 2020/2021 agricultural season, the national herd comprised 5,478,648 cattle, 3,868,402 goats, 697,910 sheep, and 278,106 pigs [9]. Cattle and pigs constitute the principal host species of relevance to this study, as the target parasites circulate primarily through bovine and porcine slaughter populations.

## Expert Selection and Invitation

Expert participation in the risk ranking exercise was secured through online recruitment. Candidates were identified through purposive sampling, drawing on national professional networks spanning

veterinary medicine, public health, parasitology, meat inspection, and biomedical science. Inclusion required a minimum of five years of relevant professional or research experience, and all prospective participants completed a conflict-of-interest declaration prior to enrolment. From an initial pool of 13 identified experts, eight agreed to participate in the criterion development phase.

A separate and distinct panel of 15 experts was subsequently convened to carry out the risk scoring exercise. Scoring was conducted independently, with each expert relying solely on their professional knowledge of local conditions and their familiarity with the relevant published literature; no empirical prevalence data from the national veterinary database were disclosed to the scoring panel prior to or during the scoring process. All participants provided written informed consent, and participation was voluntary and unpaid.

## Parasite Identification and Prevalence Assessment

A online national veterinary database, populated with routine ante-mortem and post-mortem meat inspection records from registered abattoirs across all provinces of Zimbabwe serviced by the Department of Veterinary Services Zimbabwe, was accessed in January 2025 to obtain parasite surveillance data. From this database, a comprehensive list of all parasites detected in bovine and porcine carcasses during the period, January to December 2024,was compiled. This list was then presented to the criterion-development expert panel, who were tasked with identifying, from among the detected species, those of zoonotic significance and of relevance to the One Health framework. Four parasites met these criteria and were confirmed by expert consensus for inclusion in the ranking exercise: *Taenia saginata, Taenia solium, Echinococcus granulosus*, and *Fasciola spp*. Following this confirmation, provincial and species-level prevalence data for each of the four selected parasites were extracted from the same database. Prevalence was then calculated by dividing the number of condemned organs (or carcasses) due to parasites by the total number of bovine or porcine slaughtered. These data were retained by the study team for use in the Results section and were not disclosed to the risk scoring panel, ensuring that expert scores were generated independently of the empirical surveillance record. Software used for analyses and graph presentation was R Studio v2026.01.1 + 403.

## Risk Criteria and Weighting

Risk ranking criteria and their associated weights were determined through a structured Delphi process, conducted in accordance with the general principles of the CREDES reporting guidelines for Delphi studies [10]. In the first round, the eight criterion-development experts were invited, via a structured online questionnaire, to independently propose and evaluate criteria they considered appropriate for ranking meat-borne parasites in the Zimbabwean public health context. Responses were anonymised by the study team, collated, and summarised before being redistributed to all participants at the start of the second round, allowing each expert to reconsider their assessments in light of the aggregated group feedback. This iterative process was repeated over three rounds. Consensus was operationally defined a

priori as agreement among at least 70% of participating experts on a given criterion or its weighting value. Attrition was nil across all three rounds, with all eight criterion-development experts completing the full process. Five criteria reached consensus and were formally adopted: human health impact, prevalence, transmission potential, economic impact, and controllability. Each criterion was assigned a numerical weight consistent with the methodology employed by WHO in analogous parasite risk ranking exercises [1]. Once criteria and weights were finalised, each member of the 15-member scoring panel independently assigned a score on a scale of 1 to 10 to each parasite for each criterion, drawing on their professional expertise and knowledge of the published literature rather than on any empirical prevalence data from the study. These individual scores were subsequently aggregated to produce a composite weighted risk score for each parasite, enabling their final ranking.

# Risk Score Calculation

The risk score for each parasite was calculated using the weighted sum model:

$$\mathrm{R} = \sum_{i=1}^{n} (Wi{*}Si)$$

where *Wi* is the weight of criterion *i*, *Si* is the score (ranging from 1 to 10) assigned to criterion *i*, and *n* = 5 (the number of criteria).

# Statistical Analysis

Two complementary sensitivity analyses were conducted to evaluate the robustness of the final rankings. In the first, each criterion weight was varied by ± 20% from its consensus value to assess the effect of weighting perturbations on the rank order. Spearman's rank correlation coefficient (ρ) was calculated between the base-case rankings and the rankings produced under each perturbed weighting scheme to quantify rank stability. In the second, Monte Carlo simulations (n = 1,000 iterations) were performed by introducing random variation of ± 1 unit to each expert-assigned score, yielding a distribution of composite risk scores for each parasite from which mean scores and 95% confidence intervals (CIs) were derived. A pairwise Wilcoxon signed-rank test was applied to the Monte Carlo outputs to determine the statistical significance of differences in rank between parasite pairs, with a significance threshold of α = 0.05. The proportion of simulations in which each parasite retained its base-case rank was also calculated as a direct measure of rank stability underscore uncertainty.

## Results

# Slaughter Statistics by Province

A total of 348,074 bovine and 220,644 porcine animals were recorded as slaughtered across all provinces during the year 2024 (Table 1). Slaughter volumes were highly variable by province and host species. Harare/Mashonaland East accounted for the largest share of both bovine (130,862 head; 37.6% of the national total) and porcine (197,531 head; 89.5%) slaughter, reflecting the concentration of formal

abattoir infrastructure in and around the capital. Midlands and Masvingo were the second- and third-largest contributors to bovine slaughter, with 45,264 and 41,926 head, respectively. In contrast, Manicaland recorded the lowest bovine throughput nationally (2,497 head), a figure that should be borne in mind when interpreting prevalence estimates from that province, as small denominators increase the instability of prevalence rates. Matabeleland South recorded zero porcine slaughter during the study period, precluding the calculation of porcine prevalence data for that province. The disparity in slaughter volumes between provinces reflects heterogeneity in the spatial distribution of formal livestock processing capacity across Zimbabwe.

Table 1
Total numbers of bovine and porcine animals slaughtered per province during 2024. Bulawayo/Matabeleland North and Harare/Mashonaland East were each treated as combined administrative units for analytical purposes

| Province | Bovine (n) | Porcine (n) | Total (n) |
|---|---|---|---|
| Bulawayo/Matabeleland North | 91,476 | 8,895 | 100,371 |
| Harare/Mashonaland East | 130,862 | 197,531 | 328,393 |
| Manicaland | 2,497 | 902 | 3,399 |
| Mashonaland Central | 12,786 | 2,508 | 15,294 |
| Mashonaland West | 13,933 | 902 | 14,835 |
| Masvingo | 41,926 | 438 | 42,364 |
| Matabeleland South | 9,330 | 0 | 9,330 |
| Midlands | 45,264 | 9,468 | 54,732 |
| **Total** | **348,074** | **220,644** | **568,718** |

# Parasite Prevalence

*T. saginata* and *Fasciola spp*. exhibited the highest mean national prevalence rates among the four parasites selected for risk ranking, at 1.10% and 0.64%, respectively. *E. granulosus* (hydatid cysts) and *Cysticercus cellulosae*, the larval stage of *T solium*, were recorded at lower prevalence of 0.53% and 0.08%, respectively (Fig. 2). Considerable provincial heterogeneity was observed in parasite prevalence across both host species (Fig. 3; Fig. 4). Among bovine hosts, Manicaland recorded the highest mean prevalence, driven predominantly by elevated *T. saginata* rates (3.47%), followed by Mashonaland Central. Bulawayo/Matabeleland North exhibited the lowest overall bovine prevalence across all four parasites, a pattern that may reflect more systematic ante- and post-mortem inspection protocols, lower ambient exposure, or regional differences in livestock husbandry practices. Porcine prevalence was generally lower than bovine prevalence across most provinces; however, the Midlands province recorded a notably elevated porcine prevalence, particularly for *Cysticercus cellulosae* cysticercosis, suggesting localised conditions conducive to *T. solium* transmission in that region. Matabeleland South recorded no

porcine slaughter during the study period and was accordingly excluded from porcine prevalence analyses

# Risk Ranking

Eight experts participated in the development of risk ranking criteria through a structured, three-round Delphi process. From the initial list of parasites detected in the national veterinary database, the expert panel identified four parasites of zoonotic and One Health significance for inclusion in the ranking exercise: *T. saginata, T.solium, E. granulosus*, and *Fasciola spp*. A separate panel of fifteen experts, distinct from the criterion-development group, subsequently conducted the independent risk scoring exercise.

A total of 23 experts (inclusive of both groups) participated in the evaluation. Figure 2 illustrates the distribution of respondents by educational background and field of expertise. The majority held a Bachelor of Science degree (BSc; n = 11, 47.8%), followed by Master of Science (MSc; n = 7, 30.4%) and Doctor of Philosophy (PhD; n = 2, 8.7%). Regarding field of expertise, Meat Hygiene (n = 5, 21.7%) was the most represented discipline, followed by Livestock Production and Veterinary Public Health (n = 3 each, 13.0%). This distribution reflects a multidisciplinary panel appropriate for the evaluation of meat-borne parasite risk criteria.

Five criteria were established and weighted by consensus: human health impact (weight = 0.30), prevalence (0.25), transmission potential (0.20), economic impact (0.15), and controllability (0.10) (Table 2). Human health impact was assigned the highest weight, reflecting the expert panel's collective judgement that severity and duration of disease in human populations should be the primary determinant of public health priority in the Zimbabwean context. At the national level, *T. saginata* received the highest composite risk score (5.27), followed by *T. solium* (5.09), *E. granulosus* (4.77), and *Fasciola spp*. (4.21) (Table 3)

Table 2
Risk criteria and associated weights used in the parasite risk ranking exercise.

| Criterion | Weight |
|---|---|
| Prevalence | 0.25 |
| Human health impact | 0.30 |
| Transmission potential | 0.20 |
| Economic impact | 0.15 |
| Controllability | 0.10 |

Table 3
Final national risk ranking and composite risk scores for the four selected parasites.

| Parasite | Risk Score | Rank |
|---|---|---|
| *Taenia saginata* | 5.27 | 1 |
| *Taenia solium* | 5.09 | 2 |
| *Echinococcus granulosus* | 4.77 | 3 |
| *Fasciola spp.* | 4.21 | 4 |

# Provincial-Level Rankings

Table 4
Provincial-level parasite risk rankings.

| Province | Rank 1 | Rank 2 | Rank 3 | Rank 4 |
|---|---|---|---|---|
| Harare/Mashonaland East | *T. saginata* | *T. solium* | *E. granulosus* | *Fasciola spp.* |
| Bulawayo/Matabeleland North | *T. solium* | *T. saginata* | *E. granulosus* | *Fasciola spp.* |
| Midlands | *T. solium* | *T. saginata* | *E. granulosus* | *Fasciola spp.* |
| Masvingo | *T. saginata* | *T. solium* | *E. granulosus* | *Fasciola spp.* |
| Matabeleland South | *T. saginata* | *T. solium* | *E. granulosus* | *Fasciola spp.* |
| Manicaland | *T. saginata* | *T. solium* | *E. granulosus* | *Fasciola spp.* |
| Mashonaland West | *T. solium* | *T. saginata* | *E. granulosus* | *Fasciola spp.* |
| Mashonaland Central | *T. saginata* | *T. solium* | *E. granulosus* | *Fasciola spp.* |

Provincial-level rankings broadly mirrored the national ranking, with *T. saginata* ranked first in five of the eight analytical provinces: Harare/Mashonaland East, Masvingo, Matabeleland South, Manicaland, and Mashonaland Central (Table 4). *T. solium* was ranked first in the remaining three provinces, Bulawayo/Matabeleland North, Midlands, and Mashonaland West provinces, in which porcine slaughter volumes or porcine parasite prevalence were relatively elevated, likely amplifying the expert-assigned scores for transmission potential and human health impact for that parasite. *Echinococcus granulosus* was consistently ranked third across all eight provinces, and *Fasciola spp*. was uniformly ranked fourth, indicating that both the third- and fourth-place rankings were stable across provincial contexts despite substantial variation in parasite prevalence. The inversion of the first and second rankings between *Taenia saginata* and *Taenia solium* in certain provinces highlights the sensitivity of risk rankings to local epidemiological conditions and underscores the value of conducting provincial-level analyses alongside national-level assessments.

# Monte Carlo Sensitivity Analysis

Table 5
Results of Monte Carlo simulation (n = 1,000 iterations; score variation ± 1 unit) showing mean risk scores, 95% confidence intervals, and proportion of simulations retaining the base-case rank.

| Parasite | Mean Risk Score | 95% CI | % Retaining Base Rank |
|---|---|---|---|
| *Taenia saginata* | 5.26 | [4.76, 5.76] | 82% |
| *Taenia solium* | 5.08 | [4.58, 5.58] | 78% |
| *Echinococcus granulosus* | 4.76 | [4.26, 5.26] | 85% |
| *Fasciola spp.* | 4.20 | [3.70, 4.70] | 92% |

The Monte Carlo sensitivity analysis (n = 1,000 iterations; score variation ± 1 unit) demonstrated that the base-case national ranking was robust to score uncertainty across all four parasites (Table 5). *Fasciola spp*. retained its fourth-place rank in the highest proportion of simulations (92%), followed by *E. granulosus* (85%), *T. saginata* (82%), and *T. solium* (78%). The narrower 95% confidence intervals for the lower-ranked parasites relative to those ranked first and second reflect greater separation between their composite risk scores and those of the adjacent-ranked parasite, conferring greater rank stability. The overlap in the 95% confidence intervals of *T. saginata* ([4.76, 5.76]) and *T. solium* ([4.58, 5.58]) indicates that the distinction between first and second place is the least statistically definitive of the ranking pairs, and that their relative positions may be susceptible to revision with updated scoring or alternative weighting schemes. The sensitivity analysis of criterion weights, in which each weight was varied by ± 20%, yielded a Spearman's rank correlation coefficient between the base and perturbed rankings of $\rho \approx 0.91$, indicating a high degree of overall rank stability in response to plausible perturbations in weighting assumptions. Collectively, these analyses support the conclusion that the ranking hierarchy produced in this study is robust, with the most uncertainty concentrated in the distinction between the two highest-ranked parasites.

## Discussion

This study presents the first systematic, multi-criteria risk ranking of meat-borne parasites of One Health significance from Zimbabwe. Four parasites were ranked in descending order of public health priority: *T. saginata* (rank 1), *T. solium* (rank 2), *E. granulosus* (rank 3), and *Fasciola spp*. (rank 4). A methodologically notable feature of this study is that the scoring panel conducted their assessments without access to the empirical prevalence data extracted from the national veterinary database; scores were derived exclusively from each expert's professional knowledge of local conditions and familiarity with the published literature. The expert-generated risk rankings could therefore be compared against the independently observed prevalence data as a test of whether the model's outputs were broadly predictive of the empirical surveillance record. The rankings were found to be robust to perturbations in

both criterion weights and individual parasite scores, as confirmed by sensitivity analyses. The findings have direct implications for the prioritisation of meat inspection resources, the design of surveillance programmes, and the review of food safety policy in Zimbabwe.

*T. saginata*, the beef tapeworm, was ranked first nationally by the expert panel, a judgement made without knowledge of the empirically observed prevalence figures. This ranking proved concordant with the surveillance data: *T. saginata* recorded the highest national prevalence of all four parasites at 1.10%, suggesting that expert knowledge of local epidemiological conditions and the published literature was sufficient to correctly identify it as the most prevalent hazard. The alignment between the first-place expert ranking and the highest observed prevalence constitutes evidence of the predictive validity of the scoring model with respect to this parasite. The first-place ranking reflects not only the highest prevalence but also the relative ease of transmission via the consumption of undercooked beef [12]] and the considerable aggregate economic and regulatory impacts of *T.saginata* cysticercosi [12]]. As a cestode that resides in the small intestine of the human definitive host, *T. saginata* causes human taeniasis, which manifests clinically as abdominal discomfort, nausea, and, in some cases, weight loss [12]. While the disease is rarely fatal, it imposes significant economic costs through the condemnation of infected bovine carcasses [5] at slaughter and through the management of *T. saginata* cysticercosis in livestock populations [10]. The national prevalence of 1.10% recorded in the present study is broadly consistent with the 1.6% reported by [10] from post-mortem inspection data in Matabeleland Province, although considerably lower than the 38% detected by ELISA-based serology in the same region [13]. This divergence between inspection-based and serological estimates is well documented in the literature and underscores the sensitivity limitations of ante-mortem and post-mortem visual inspection as a sole detection method [12]. Manicaland province recorded the highest provincial prevalence for *T. saginata* (3.47%), a finding that may reflect differences in sanitation infrastructure, the prevalence of open defecation, water source quality, and the extent to which cattle graze on land contaminated with human faeces, all established risk factors for *T.saginata* cysticercosis [11]. The high ranking of *T. saginata* in five of eight analytical provinces further corroborates its status as the primary meat-borne parasitic hazard of concern in the Zimbabwean livestock sector [13].

*Taenia solium*, the pork tapeworm, was ranked second nationally by the expert panel, yet recorded the lowest national prevalence of all four parasites at 0.08%. This represents the most notable divergence between expert-predicted risk rank and observed prevalence order in the study, and it is instructive precisely because the scoring panel operated without knowledge of the empirical prevalence data. The divergence indicates that expert judgement, drawing on knowledge of local conditions and the published literature, assigned substantially greater weight to the severity of *T. solium*'s consequences in human health than its low recorded prevalence would suggest. The severe consequences attributable to *T. solium*, in particular, neurocysticercosis, which can cause seizures, headaches, hydrocephalus, and death [4], resulted in high expert scores for the human health impact criterion, which carried the greatest weighting (0.30). This finding raises an important interpretive question: whether the second-place ranking reflects a genuine public health priority that the prevalence data underestimate, owing to the known insensitivity of post-mortem visual inspection for detecting porcine cysticercosis, or whether it

constitutes a degree of over-ranking relative to the parasite's true burden in the Zimbabwean livestock system.In Matabeleland South ,a province which recorded zero official slaughter of porcines,the experts ranked it second.It is uncommon in Zimbabwe for slaughter and processing of food animals to occur outside of official channels hence slaughter figures can be lower than the actual [14]. Humans serve as both the definitive host for intestinal taeniasis, following ingestion of pork containing *Cysticercus cellulosae*, and as accidental intermediate hosts in cases of human cysticercosis, typically acquired through ingestion of *T. solium* eggs via faeco-oral contamination [4]. The mean national prevalence of 0.08% recorded in the present study is somewhat higher than the 0.05% reported by [15] for the Matabeleland region but lower than the 0.34% documented nationally by [16] two decades earlier, suggesting a possible temporal decline in prevalence, though methodological differences preclude definitive comparisons. The first place ranking of *T. solium* in Bulawayo/Matabeleland North, Midlands, and Mashonaland West provinces is consistent with the comparatively higher porcine slaughter volumes and porcine parasite prevalence in those provinces, which would amplify estimated transmission potential at the provincial level. *T. solium* is widely recognised as a priority zoonosis in sub-Saharan Africa [4], and its second-place national ranking in this study reinforces the importance of integrating porcine *T. solium* cysticercosis control into broader One Health strategies in Zimbabwe .

*E. granulosus*, the causative agent of cystic echinococcosis (CE), was ranked third nationally, with a recorded prevalence of 0.53%. CE is a chronic, potentially life-threatening condition characterised by the formation of hydatid cysts in soft tissues, principally the liver and lungs of both livestock and humans [14]. The lifecycle is perpetuated when infected offal is consumed by canid definitive hosts, which subsequently excrete oncospheres capable of infecting intermediate hosts including cattle, sheep, and humans [14]. The third-place ranking of *E. granulosus* reflects its lower human-to-human transmission potential relative to the two *Taenia* species, and the comparative feasibility of implementing targeted control measures, including dog deworming programmes and public education regarding the safe disposal of infected offal, which can interrupt the livestock-canid transmission cycle effectively. Nonetheless, CE remains a significant public health and economic burden in Zimbabwe, as demonstrated by [15], who documented substantial offal condemnation losses attributable to CE in cattle slaughtered in the Matabeleland region. The consistent third-place ranking of *E. granulosus* across all eight provinces, irrespective of local prevalence variation, suggests that its intermediate risk profile is a stable feature of the hazard's characteristics rather than an artefact of local epidemiological conditions.

*Fasciola spp.* was ranked fourth by the expert panel, yet it recorded the second-highest national prevalence (0.64%) of all four parasites,higher than both *E. granulosus* (0.53%) and *T. solium* (0.08%). This is the second notable divergence between expert-predicted risk rank and observed prevalence order, and it was produced entirely through expert knowledge and literature review without recourse to the empirical prevalence data. The experts' assignment of the lowest composite risk score to *Fasciola spp*. reflects the recognised low severity of trematode hepatic fasciolosis in humans relative to the neurological and oncogenic sequelae of the cestode infections [1]: comparatively low scores were assigned for human health impact and transmission potential, and the former criterion carries the

dominant weighting in the model. That the expert panel correctly identified *Fasciola spp*. as a lower human health priority than all three cestode parasites, despite its higher recorded prevalence relative to two of them, provides further evidence of the model's discriminant validity, demonstrating that expert scoring based on knowledge and literature was capable of separating parasites by health impact severity independently of their prevalence rank. This disjunction between prevalence rank and risk rank also illustrates a structural strength of the multi-criteria approach [1]: it prevents high prevalence alone from dominating the risk hierarchy, ensuring that human health severity, the highest-weighted criterion, exerts appropriate influence on the outcome. However, it is important to consider this ranking alongside a critical assessment of the prevalence data underpinning it. The national prevalence of 0.64% recorded in the present study is markedly lower than the 37% reported by [16] over a ten-year retrospective study period, representing a discrepancy in excess of 50-fold. Several methodological and contextual factors are likely to contribute to this difference. The gross post-mortem visual inspection used as the basis for the national veterinary database has substantially lower sensitivity than serological or coprological methods for detecting fasciolosis, particularly in cases of subclinical infection or low worm burdens in which hepatic lesions may be subtle or absent [18]. Under-recording in the national database, a known limitation of passive surveillance systems in resource-constrained settings [14], may further suppress reported prevalence. Temporal changes in the abundance and distribution of lymnaeid snail intermediate hosts, driven by land use change, drought, or altered rainfall patterns, could also account for genuine changes in fasciolosis prevalence over time [17]. These considerations do not invalidate the ranking assigned to *Fasciola spp*., but they underscore the need for periodic active surveillance using sensitive diagnostic methods to validate and update the prevalence estimates on which risk rankings are based. The spread of *Fasciola spp.* is strongly governed by environmental conditions favouring lymnaeid snail proliferation, and climate-associated changes in wetland and waterway habitats could alter the epidemiological trajectory of this pathogen in Zimbabwe in the coming decades [17].

Risk ranking exercises of this kind serve a foundational function in food safety governance: by systematically ordering hazards according to their public health significance, they enable national regulatory authorities to establish evidence-based priorities for meat inspection, allocate finite resources to the most pressing risks, and evaluate whether existing policy frameworks are proportionate to the burden posed by individual hazards [19]. Considered alongside the empirical prevalence data, the expert-generated rankings in this study demonstrate partial predictive validity. The model correctly predicted the first-place prevalence rank of *T. saginata* and the third-place rank of *E. granulosus*; however, it placed *T. solium* second despite its lowest recorded prevalence, and ranked *Fasciola spp.* last despite its second-highest prevalence. These divergences are not methodological failures but rather reflect the intended operation of a multi-criteria framework in which human health impact, rather than prevalence alone, is the primary determinant of rank. In the Zimbabwean context, the rankings produced here suggest that *T. saginata* cysticercosis inspection and control programmes should be accorded the highest operational priority, followed by interventions targeting *T. solium* in pig production and slaughter systems. The consistent identification of *Fasciola spp*. as the lowest-ranked hazard, despite its higher recorded prevalence, provides evidence-based justification for the relative prioritisation of the cestode parasites

over trematodes in national resource allocation decisions, though this should not be interpreted as a signal to deprioritise fasciolosis surveillance entirely, given the uncertainties surrounding prevalence data.

Several limitations of the present study warrant acknowledgement. The reliance on national veterinary inspection databases as the primary source of prevalence data introduces the potential for systematic under-detection, as discussed above, and the overall quality and completeness of the database across all provinces could not be independently verified. With respect to the scoring process, expert scores in this study were generated without access to empirical prevalence data, relying instead on professional knowledge and the published literature. While this approach preserves the independence of the expert-generated rankings from the observed surveillance data, thereby permitting the comparison of ranked outputs against prevalence as a form of predictive validity assessment it also means that expert scores for the prevalence criterion reflect perceived rather than measured prevalence. Where expert perceptions of local prevalence diverge materially from the empirical record, as appears to be the case for *T. solium* and *Fasciola spp*., this divergence may warrant re-examination in future iterations of the ranking using a design that either informs experts with verified prevalence data or explicitly tests blinded against informed scoring designs. Additionally, while the Delphi process achieved consensus among the expert groups, the relatively small number of experts involved (eight in criterion development and fifteen in scoring) limits the generalisability of the expert opinion component and the degree to which the weighting scheme can be assumed to reflect broader national stakeholder views. Future risk ranking exercises in Zimbabwe should consider expanding expert representation to include consumer advocacy groups, smallholder farmers, and community health workers, in addition to technical specialists. Notwithstanding these limitations, this study provides the first nationally applicable, quantitative risk ranking of meat-borne parasites in Zimbabwe and offers a replicable methodological framework that can be updated as new prevalence and burden data become available.

# Declarations

**Declaration of Funding statement**

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

**Data Availability**

All data supporting the findings of this study are available within the paper.

**Ethics approval**

1. This study (human research participant) was approved by the Joint Research Ethics Committee of the University of Zimbabwe (JREC/UZ/2070) on 29 March 2025, in accordance with the ethical guidelines and regulations governing research involving human participants established by the Joint

Research Ethics Committee of the University of Zimbabwe. All participants were adults who voluntarily completed a questionnaire in their capacity as subject-matter experts. Prior to participation, all respondents were fully informed of the purpose of the study and provided their informed consent. Participation was entirely voluntary, and participants were assured of confidentiality and anonymity in the handling of all data collected.

2. This research (Animal) was conducted retrospectively from data obtained from meat inspection records kept at the Directorate of Veterinary Services, Harare,Zimbabwe offices. The need for ethical approval was waived off by the ethical committee of the Directorate of Veterinary Services on 13 March 2025 as the research did not involve live animals.

**Consent to publish**

Not applicable.

**Consent to participate**

All participants involved in this study were experts who voluntarily participated in an online questionnaire. Prior to their participation, all respondents were provided with a clear description of the study's purpose, objectives, and scope. Participants were informed that their involvement was entirely voluntary, that they could withdraw at any time without consequence, and that no personally identifiable information would be collected or disclosed. Respondents provided their implicit informed consent by completing and submitting the questionnaire. All data collected were treated with strict confidentiality and used solely for the purposes of this research. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

**Clinical trial number**

Not applicable.

**Conflicts of Interests**

The authors declare no conflicts of interest.

**Author Contributions**

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# Figures




**Figure 1**

*Map of Zimbabwe showing its ten administrative provinces.*

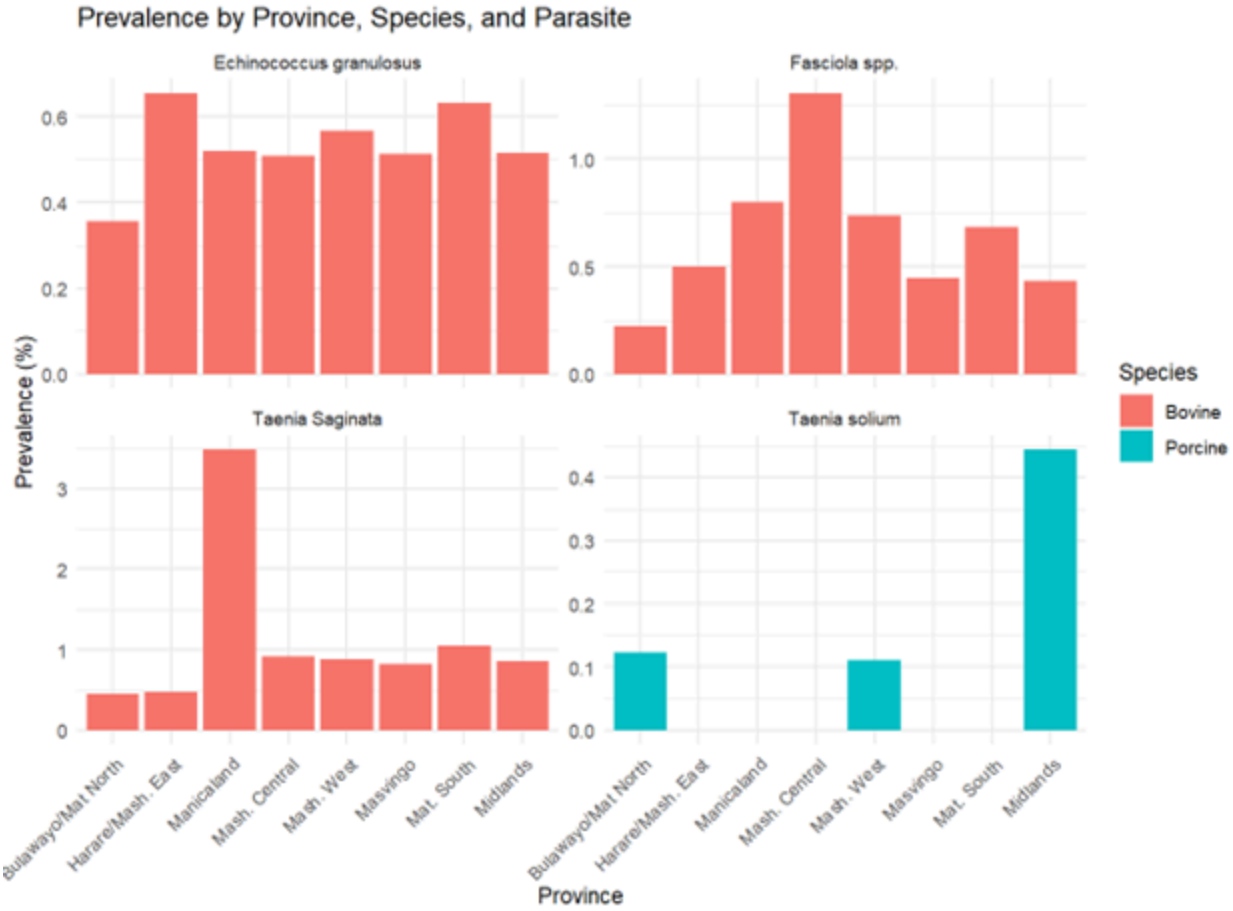



**Figure 2**

*Mean prevalence rate (%) of each parasite across all provinces and host species*

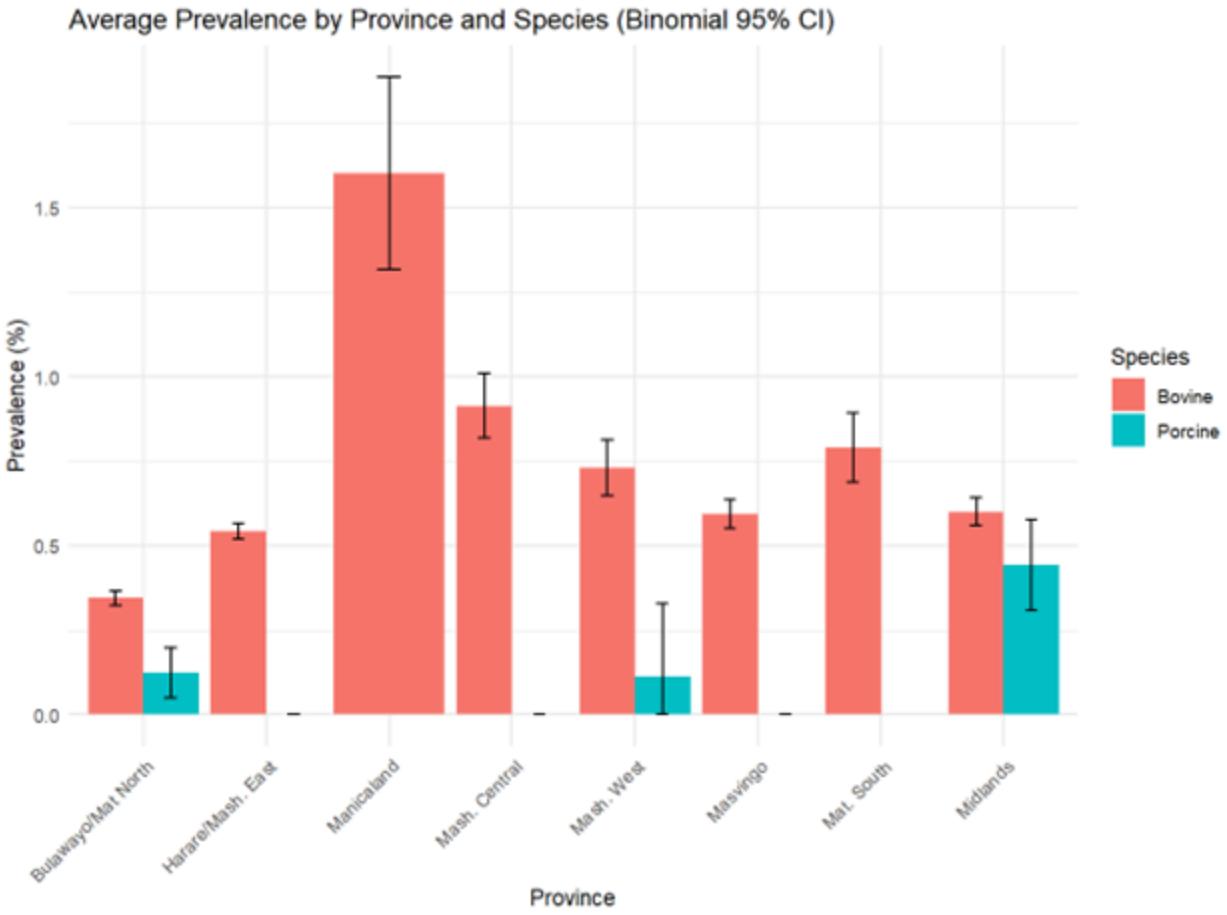
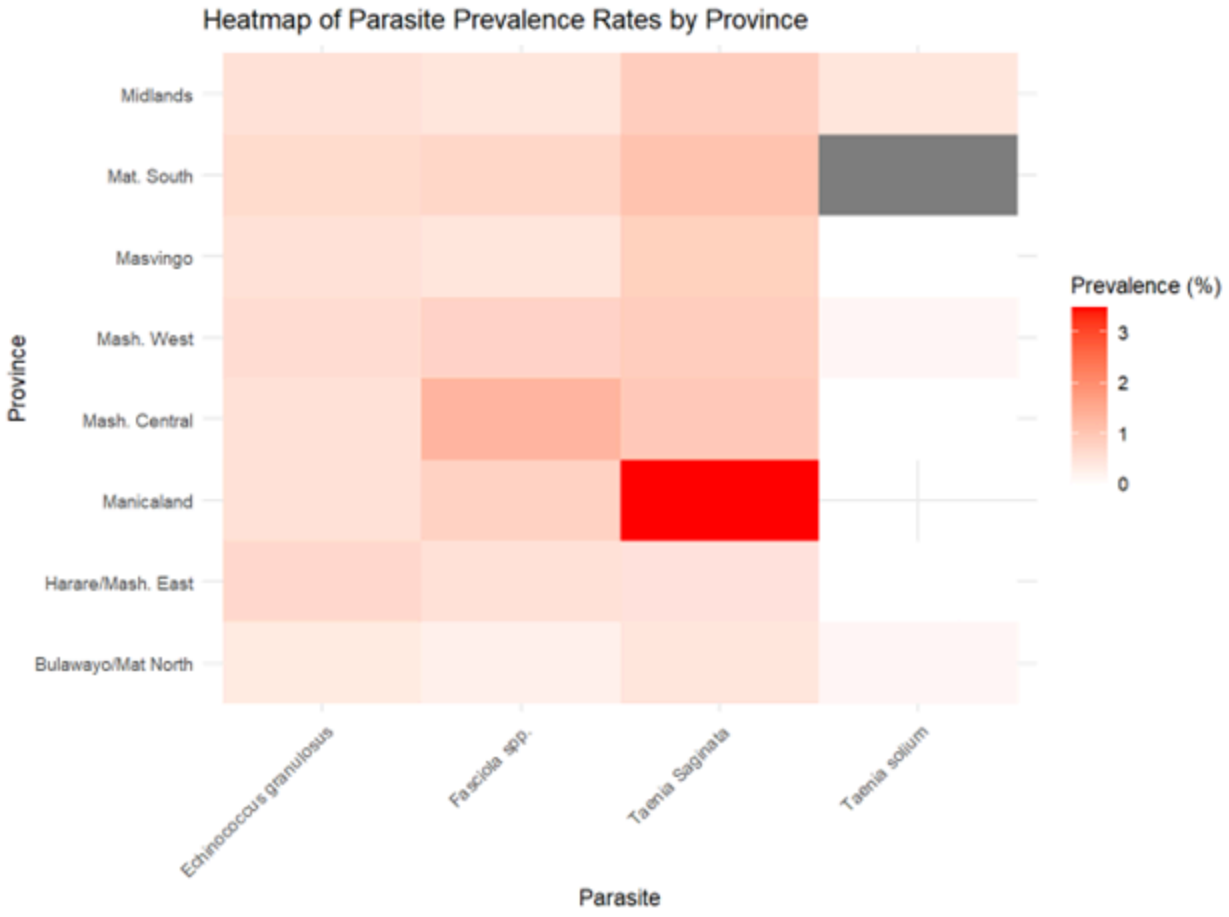


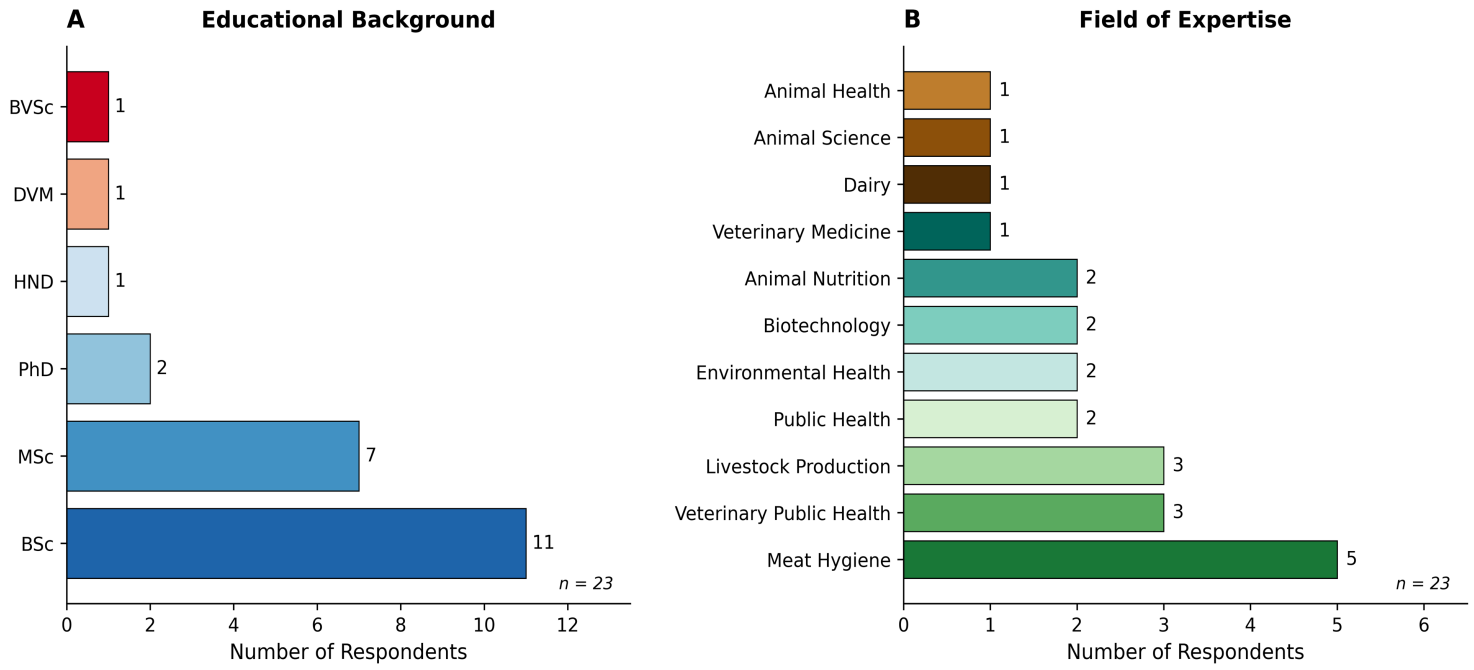

**Figure 3**

*Average parasite prevalence rate (%) by province and host species (bovine vs. porcine).*




## Figure 4

*Heatmap of parasite prevalence rates (%) by province. Darker shading indicates higher prevalence.*




## Figure 5

Legend not included with this version.