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Epidemiological Study and Spatial Distribution of Beef Cattle Paramphistomosis in Manokwari Regency, West Papua, Indonesia

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ABSTRACT

Livestock productivity can decrease due to paramphistomosis caused by *Paramphistomum spp.* This study aimed to determine the prevalence of the disease, analyze the risk factors, and present a distribution map of paramphistomosis in beef cattle in Manokwari Regency, West Papua. Using simple random sampling, a total of 1336 beef cattle fecal samples were collected from 206 smallholder farms in seven districts in Manokwari Regency from December 2023 to February 2024. Risk factor analysis was conducted to see associations with disease incidence and GIS maps were created to visualize the prevalence distribution of paramphistomosis in Manokwari regions. The overall prevalence of paramphistomosis was 45.56%, while at the farm level, it was 75.73%. The sampling location, livestock origin, feeding method, drinking water sources, and farmers' education level were risk factors that correlated ($P<0.05$) with the prevalence of *Paramphistomum spp.* infection in beef cattle. Manokwari Selatan District was detected as an area with a high prevalence of paramphistomosis. Based on the epidemiological data, it can be concluded that the level of endemism of paramphistomosis is quite high in Manokwari Regency, West Papua. The results of this study reveal the role of livestock management systems and farmer education factors in influencing the geographic heterogeneity of the prevalence of beef cattle paramphistomosis. These risk factors can be used to develop paramphistomosis control strategies, farmers are adequately educated about health problems of livestock that these parasitic infections cause to their livestock productivity.

Key words: Beef cattle, Distribution, Epidemiology, Manokwari, Paramphistomosis.

INTRODUCTION

In Indonesia, endoparasitic infections are the dominant parasitic disease in ruminants (Hambal et al. 2020; Nurcahyo et al. 2021; Martindah et al. 2023). Paramphistomosis is a disease caused by parasites classified in the family Paramphistomidae, commonly known as rumen flukes (Zheng et al. 2014; Padak and Karakuş 2021), e.g. *Paramphistomum cervi*, *Paramphistomum leydeni*, or *Calicophoron daubneyi* (Lotfy et al. 2010; Rafiq et al. 2020). This *Paramphistomum spp.* is commonly found in the rumen and ruminant reticulum (Kifleyohannes et al. 2015). This pathogenic parasite is one of the most neglected parasitic diseases worldwide. However, tropical and subtropical areas especially those in Africa, Asia, Australia, Eastern Europe and Russia generally record high prevalence rates (Hotessa and Kanko 2020).

Paramphistomosis is usually subclinical and does not exhibit obvious clinical symptoms. Previously considered a minor issue, it is now reported as a main cause of livestock production losses. In chronic infection, adult flukes in the rumen of cattle can cause reduced feed conversion, weight loss, decreased milk production, infertility, and even mortality (Ozdal et al. 2010; Admasu and Nurlign 2014; Ayalew et al. 2016). In acute cases, thickening of the intestinal mucosa and submucosa occurs (Atcheson et al. 2020). Several studies report increased morbidity, particularly in animals reared under traditional farming systems due to stress from nutritional deficiencies

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(Dorny et al. 2011; González-Warleta et al. 2013). High mortality rates in both young and adult ruminants due to rumen flukes (Huson et al. 2017; Delafosse 2022) results in significant economic losses (Dorny et al. 2011), estimated up to 3.2 million USD per year (Bekele et al. 2010; Elelu and Eisler 2018).

The epidemiology of paramphistomosis in cattle is influenced by the interaction between the parasites, host, and environment (Martinez-Ibeas et al. 2016). Outbreaks of paramphistomosis in goats and cattle, as revealed by several laboratory studies, are associated with various epidemiological factors, including livestock management systems and grazing patterns (Kumar et al. 2011; Ferreras et al. 2014), the biological potential of snail hosts (Khan and Maqbool 2012; Megersa et al. 2024) and the ability of adult flukes to infect both intermediate and definitive hosts (Preethi et al. 2020; Delafosse 2022).

There have been only a few sporadic studies on the prevalence of paramphistomosis conducted in limited areas of Indonesia, including 10.03% in Prafi District, Manokwari Regency (Purwaningsih et al. 2018), 57% in Libureng, Bone Regency (Yuliza and Sirupang 2015) and 15% at the Denpasar City slaughterhouse (Lestari et al. 2017). Despite its importance as a beef cattle center, Manokwari Regency in West Papua lacks comprehensive data on paramphistomosis, including its prevalence, risk factors, and spatial distribution. This gap hinders effective disease control strategies. This study addresses the issue by providing baseline data and applying a regional-spatial approach to better understand the disease's epidemiology in Eastern Indonesia. This study's objectives were to determine the disease prevalence, carry out a regional investigation of the risk factors contributing to paramphistomosis in beef cattle, and create a disease distribution map for the Manokwari Regency, West Papua.

MATERIALS AND METHODS

Study area

This cross-sectional investigation was conducted from December 2023 to February 2024 to determine the prevalence of *Paramphistomum spp.* infection in beef cattle in Manokwari Regency, West Papua. Manokwari Regency is located in the bird's head region of Papua Island, positioned between 0º15'-3º25'S and 132º35'-134º45'E. The territory, which is administratively separated into nine districts, has a varied topography including lowlands, hills, and mountainous areas. It is also abundant in natural resources. Manokwari Regency was chosen for this study due to its role in Indonesia's eastern beef cattle development program and its unique ecological and livestock conditions. Understanding paramphistomosis prevalence and risk factors here is crucial for effective disease control and supporting regional animal health interventions.

Study design and sampling

A double-stage sampling method was employed in this study. Districts were selected using simple random sampling, while beef cattle farms and individual animals were selected conveniently from villages within each district. The total sample size for each district was determined based on probability proportional to population size. The sample size was calculated using the formula $n = 4PQ/L^2$, where n = required sample size, P = assumed prevalence in the study area, Q = (1 – P) and L = desired precision (Dohoo et al. 2003). An assumed prevalence of 20% (FAO, 2016), a precision of 5% (L=0,05), and a 95% confidence level were applied, resulting in a required sample size of 256. To correct for potential bias in the double-stage sampling process, the sample size was multiplied by 5, leading to a target of 1280 samples (Thrusfield 2018). However, the study ultimately included 1336 cattle from seven districts: Manokwari Utara (n=75), Manokwari Barat (n=49), Prafi (211), Masni (n=457), Sidey (n=282), Warmare (n=119), and Manokwari Selatan (143).

Data collection

Fresh faecal samples of 10-20g were taken after cattle defecation. The feces were placed into labeled plastic bags containing 10% formalin as a preservative and stored at 4℃ until examination. Questionnaires were provided with the provision of information from the host (livestock), management system, and livestock owner and conducted by enumerators. Data were collected by direct observation of livestock and by interviewing the owners. Variables included in this study include: host variables of age, gender, BCS, number of livestock in the population, and origin of livestock; management system variables namely rearing system, deworming program, type of feed, feeding method, forage collection time, source of livestock drinking water, pen floor, pen sanitation and pen drainage; livestock owner variables namely education level, farming experience, and purpose of raising livestock.

The collected data were entered into Microsoft Excel 2019 and the prevalence of paramphistomosis in Manokwari Regency was obtained by the formula $P = P_i / P_s$, where P_i is the number of cattle infected with *Paramphistomum spp.* and P_s is the number of samples examined. Meteorological data and prevalence statistics were transferred to ArcGIS 10.3 and QGIS 3.26.3 databases as attribute tables and attached to maps of Manokwari Regency. Data regarding environmental variables (land cover and soil type) for geographical coordinates were provided by the Indonesian Geospatial Information Agency (BIG) in the form of geospatial maps of the Indonesian Earth Form (RBI).

Coprological examination

Fecal samples were examined using the sedimentation technique. After thoroughly mixing the fecal sample, 3g of fecal sample was taken and put into a glass 1 containing 42mL of tap water. It was then mixed evenly with a stirring device. The filtered material was poured into a test tube and centrifuged at 1500rpm for 5 minutes. After centrifugation, the supernatant was removed and a few drops of 5% methylene blue were added. Then the sediment was transferred to a slide covered with a coverslip and examined under a 10x magnification objective microscope. *Paramphistomum spp.* eggs were identified based on their characteristic morphological features as described by Urquhart et al. (2007). The McMaster method was used to count eggs per gram (EPG) in positive samples. The total number of eggs counted in one slide was multiplied by 100 to obtain the EPG. Animals were considered positive for paramphistomosis if *Paramphistomum spp.* eggs were observed during microscopic examination.

Geographic information system mapping

Map making was done using ArcGIS and QGIS software. Sampling results in the form of coordinate points and results are then converted into a shapefile form for further display on the parameter layer. Data related to administrative boundaries and land cover/use were obtained from the Geospatial Information Agency (BIG).

Statistical Analysis

Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 24.0 (IBM Corp., NY, USA). First, data were organized for univariate analysis to determine the influence of individual risk factors on the incidence of paramphistomosis. Variables with a P-value <0.25 were retained as potential candidates for multivariate analysis (multiple logistic regression with backward stepwise elimination). The final model was constructed with a significance level of P<0.05 to determine statistically significant risk factors. Infection intensity was determined based on EPG count in infected animals, and classified as light (<200 EPG), moderate (200–500EPG), and severe (>500EPG) (Pal et al. 2015; Baruah and Bhattacharyya 2016).

RESULTS

Prevalence, intensity and spatial distribution of paramphistomosis in beef cattle

Six hundred and nine of the 1336 fecal samples were examined and tested positive for one or more *Paramphistomum spp.* eggs, with an overall prevalence of 45.56%. The prevalence of paramphistomosis at the farm level was 75.73%. The overall infection intensity was 374.38±0.68 eggs per gram of feces in Manokwari's seven districts. The spatial distribution of the prevalence and intensity of *Paramphistomum spp.* infection ranged from 13.3% - 63.6% and 130±4.83 – 465.69±5.12, respectively, in seven districts of Manokwari. The highest prevalence and intensity of infection were found in Manokwari Selatan District and the lowest in Manokwari Utara District (Table 1). The map highlights variations in infection prevalence across different districts, indicating regional disparities in disease burden (Fig. 1).

Table 1: Prevalence and intensity of infection with paramphistomosis in Manokwari Regency

District (n sample)	Infection (Prevalence) (%)	EPG	
		Range	Mean±SE
Manokwari Utara (75)	10 (13.3)	100-200	130.00±4.83
Manokwari Barat (49)	10 (20.4)	100-600	158.11±15.81
Prafi (211)	86 (40.8)	100-900	225.58±1.95
Masni (457)	257 (56.2)	100-3400	392.61±1.84
Sidey (282)	124 (44.0)	100-1900	385.16±3.11
Warmare (119)	31 (26.1)	100-1200	274.19±7.63
Manokwari Selatan (143)	91 (63.6)	100-2500	495.69±5.12
Total (1.336)	609 (45.56)	100-3400	374.38±0.68

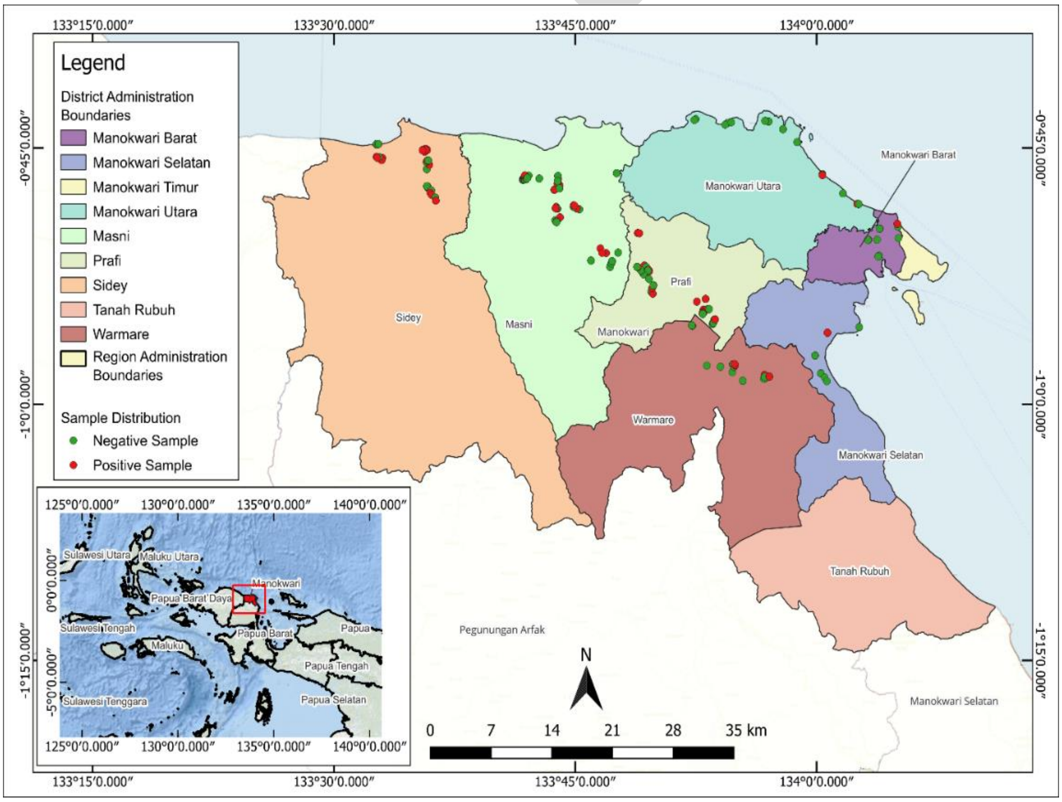

Fig. 1: Research sampling points. Red and green dots represent cattle positive or negative for *Paramphistomum spp.* infection, respectively.

Potential factors associated with paramphistomosis in beef cattle

Potential factors correlated with the prevalence of paramphistomosis in beef cattle in Manokwari Regency based on a chi-square test with significantly different prevalence values (P<0.05) were sampling location, sex, origin of livestock, rearing system, type of feed, feeding method, water source, farmer education, and number of livestock ownership (livestock population). The prevalence of paramphistomosis was recorded significantly higher in Manokwari Selatan District compared to the other six districts (chi-square [χ^2]=104.24, P=0.000). Females (48.0%) had a significantly higher prevalence of paramphistomosis than males (42.2%) (χ^2 = 4.344, P = 0.04). Whereas non-purchased origins (own breed stock) recorded a significantly higher prevalence (47.8%) compared to purchased origins (40.5%) (χ^2=6.018, P=0.016).

The prevalence of paramphistomosis on farms with extensive rearing systems was significantly higher compared to semi-intensive and intensive rearing systems (χ^2=14.855, P=0.001). Cattle-fed forage (46.3%) had a significantly higher prevalence compared to those fed forage and bran (33.8%) (χ^2=4.600, P=0.034). Farms using the cut-and-carry feeding method had a significantly lower prevalence (41.3%) compared to the grazing method (48.9%) (χ^2=7.092, P=0.009). Farms using water sources from rivers or streams or irrigation (50.8%) had a significantly higher prevalence compared to water sources from wells (38.6%) (χ^2=19.672, P=0.000). Farms managed by farmers with primary education had a significantly higher prevalence compared to farms managed by highly educated farmers (χ^2=7.288, P=0.008). In addition, the prevalence of farms with more than 10 heads was significantly higher than farms with 1–10 heads (χ^2=16.865, P=0.000). Table 2 presents the breakdown of prevalence by variable.

Table 2: Results of univariate analysis between potential risk factors and prevalence of paramphistomosis in beef cattle in Manokwari Regency, West Papua

Factors	Categories	Infected (%)	χ2	P-value	OR (95% CI)
Location	Manokwari Utara (75)	10 (13.3)	104.24	0.000*	11.37 (5.39 – 24.03)
	Manokwari Barat (49)	10 (20.4)			
	Prafi (211)	86 (40.8)			
	Masni (457)	257 (56.2)			
	Sidey (282)	124 (44.0)			
	Warmare (119)	31 (26.1)			
	Manokwari Selatan (143)	91 (63.6)			
Age	0 – 2 years (463)	204 (44.1)	0.663	0.416	1.099 (0.876 – 1.378)
	> 2 years (873)	405 (46.4)			
Sex	Male (561)	237 (42.2)	4.344	0.037*	1.262 (1.014 – 1.571)
	Female (775)	372 (48.0)			
Livestock origin	Non-purchased (938)	448 (47.8)	6.018	0.014*	0.743 (0.586 – 0.942)
	Purchased (398)	161 (40.5)			
Body Condition Score (BCS)	< 3 (375)	161 (42.9)	1.476	0.224	1.161 (0.813 – 1.476)
	≥ 3 (961)	448 (46.6)			
Rearing system	Extensive (915)	448 (49.0)	14.855	0.001*	1.770 (1.290 – 2.429)
	Semi-intensive (219)	90 (41.1)			
	Intensive (202)	71 (35.1)			
Deworming program	Yes (814)	361 (44.3)	1.281	0.258	1.136 (0.911 – 1.416)
	No (522)	248 (47.5)			
Type of feed	Forage (1259)	583 (46.3)	4.600	0.032*	0.591 (0.364 – 0.960)
	Forage + bran (77)	26 (33.8)			
Forage collection time	Morning (254)	122 (48.0)	1.717	0.197	0.825 (0.619 – 1.100)
	Morning and afternoon (705)	305 (43.3)			
	Afternoon (377)	182 (48.3)			
Feed method	Cut & carry (557)	230 (41.3)	7.092	0.008*	1.347 (1.082 – 1.678)
	Grazing (779)	379 (48.9)			
Water source	River, irrigation (768)	390 (50.8)	19.672	0.000*	0.608 (0.488 – 0758)
	Well (568)	219 (38.6)			
Sanitation of pen	Clean (237)	108 (45.6)	0.000	0.996	1.001 (0.755 – 1.327)
	Dirty (1099)	501 (45.6)			
Type of floor	Cement (262)	113 (43.1)	0.791	0.374	1.132 (0.862 – 1.486)
	Land (1074)	496 (46.2)			
Drainage of pen	Yes (62)	24 (38.4)	1.239	0.266	1.344 (0.797 – 2.268)
	No (1274)	585 (45.9)			
Footing ground	Muddy (183)	85 (46.4)	5.430	0.066	1.136 (0.842 – 1.532)
	Dry (1034)	458 (44.3)			
	Mud 119)	66 (55.5)			
Education level of Famer	Basic (611)	303 (49.6)	7.288	0.007*	0.742 (0.598 – 0.922)
	Higher (725)	306 (42.2)			
Farmer experience	≤ 5 tahun (121)	45 (37.2)	3.779	0.052	1.463 (0.995 – 2.151)
	> 5 tahun (1215)	564 (46.4)			
Purpose of farming	Daily need (1303)	177 (44.1)	0.482	0.488	1.087 (0.859 – 1.375)
	Savings (306)	432 (46.2)			
Number of livestock in the population	1 – 10 heads (694)	279 (40.2)	16.865	0.000*	1.573 (1.267 – 1.954)
	> 10 heads (642)	330 (51.4)			

*Statistically significant (P<0.05), χ2 = Chi-square.

Risk factors associated with paramphistomosis in beef cattle

The study's logistic regression model indicated that the sampling location, livestock origin, feeding method, water source, and farmer education level were identified as risk factors. The prevalence of paramphistomosis was 11.46 times higher in cattle located in Manokwari Selatan District compared to cattle located in the other six districts. Livestock of non-purchased origin (own breeding stock) had 0.32 times less risk of *Paramphistomum spp.* infection compared to those of purchased origin. Livestock fed by the grazing method were 1.67 times more susceptible to *Paramphistomum spp.* infection than livestock fed by the cut-and-carry method. Livestock whose source of drinking water was well were 0.44 times less likely to be infected with *Paramphistomum spp*. compared to livestock fed from river water channels. Farmers with basic education had 1.31 times the risk of *Paramphistomum spp.* infection compared to livestock managed by highly educated farmers (Table 3).

Intensity of *Paramphistomum spp.*

Three categories of *Paramphistomum spp.* infection intensity were based on EPG from laboratory examination results. 40.56% (247/609) cattle were lightly infected, 38.26% (233/609) were moderately infected and 21.18% (129/609) were severely infected (Table 4). The mean (± standard error) EPG was 374.38 ± 0.68 (range 100–3400).

DISCUSSION

Currently, beef cattle farming in Indonesia is largely a smallholder farming business, traditionally reared alongside food crops (Rusdiana and Praharani 2019). The result obtained from the fecal sedimentation method in this study, 45.56%, were in line with the prevalence reported in Yogyakarta, Indonesia (47.00%) **(**Rinca et al. 2019), Pekanbaru, Indonesia (46.55%) (Rozi et al. 2015), and Banda Aceh, Indonesia (48.54%) **(**Hambal et al. 2020). The prevalence of paramphistomosis in Manokwari falls within the range reported in 40 Asian countries by Tookhy et al. (2022) which is 6.45 – 90.6%. This prevalence is lower than that recorded in Bone Regency, Indonesia (57%) (Yuliza and Sirupang 2015). However, it is higher than previous studies conducted in Central Jawa, Indonesia (4%) (Hamid et al. 2016), Prafi District, Indonesia (10.03%) (Purwaningsih et al. 2018) and Lima Puluh Kota Regency, Indonesia (24.14%) **(**Zelpina et al. 2023), though still lower than the prevalence in Central Sulawesi, Indonesia (69.94%) (Budiono et al. 2018). The prevalence found in this study is also higher compared to other countries, including Thailand (33.8%) (Japa et al. 2020), India (24.29%) (Preethi et al. 2020), Iran (19.5%) **(**Hajipour et al. 2021), Etiopia (21.9%) **(**Sirika et al. 2022), Bangladesh (28.3%) (Sayed et al. 2023) and South-eastern Mexico (33.4%) (Hernández-Hernández et al. 2023). However, the identified prevalence infection in this study was lower than prevalence reported in Nigeria (62.6%) (Opara et al. 2022) and Pakistan (56.25%) (Rizwan et al. 2022). The result of this study was in agreement with previous study reported in Malaysia (46.9%) (Che-Kamaruddin and Isa 2023). Geographical and environmental variables may be the cause of these differences. Amphistome prevalence in Iran was found to be significantly correlated with age, season, breed, water source, grazing system, and pasture **(**Hajipour et al. 2021).

Differences in prevalence between regions may be due to variations in husbandry systems, sample size, livestock composition, biological potential of host intermediates, topography and climate, sampling locations, resistance of metacercariae in the environment and diagnostic techniques (Melaku and Addis 2012; Khedri et al. 2015). Similarly, variations in prevalence between countries could result from variations in farmer knowledge, farming practices and meteorological and environmental factors (Mehmood et al. 2017). The parasite needs a good environment, temperature, and humidity to complete their life cycle (Howell and Williams 2020).

Table 3: Results of multivariate logistic regression analysis for potential risk factors of paramphistomosis in beef cattle in Manokwari Regency, West Papua

Factors	B	S.E.	Wald	Sig.	OR	95% CI
Location (Manokwari Selatan)	2.439	0.414	34.690	0.000*	11.459	5.090 – 25.800
Livestock origin (non-purchased)	-0.385	0.146	7.003	0.008*	0.680	0.511 – 0.905
Feeding method (grazing)	0.513	0.148	12.068	0.001*	1.670	1.250 – 2.230
Water source (well)	-0.580	0.146	15.736	0.000*	0.560	0.420 – 0.746
Farmer education level (basic)	0.272	0.137	3.958	0.047*	1.313	1.004 – 1.716
Farmer experience (≤ 5 years)	0.441	0.236	3.486	0.062	1.555	0.978 – 2.471

B = Estimated value, S.E. = Standard error, Wald = Wald chi-square test, Sig. = p-value, OR = Odds ratio, CI = Confidence interval; *Statistically significant (P<0.05).

Table 4: Intensity of *Paramphistomum spp*. in beef cattle in Manokwari Regency, West Papua, Indonesia by animal factor (n=609)

Factors	Category	Frequency	Intensity of infection, frequency (%)		
			Light	Moderate	Severe
Age	< 2 years	206	78 (37.86)	89 (43.20)	39 (18.93)
	≥ 2 years	403	162 (40.20)	148 (36.72)	93 (23.08)
Sex	Male	232	108 (46.55)	84 (36.21)	40 (17.24)
	Female	377	134 (35.54)	152 (40.32)	91 (24.14)
Body Condition Score	< 3	166	62 (37.35)	73 (43.98)	31 (18.67)
	≥ 3	443	185 (41.76)	158 (35.67)	100 (22.57)
Fecal consistency	Liquid	91	38 (41.76)	36 (39.56)	17 (18.68)
	Soft	355	153 (43.10)	119 (33.52)	83 (23.38)
	Normal	163	57 (34.97)	74 (45.40)	32 (19.63)

This study found many factors that may predict paramphistomosis prevalence in beef cattle in Manokwari Regency. These factors include the sampling location, livestock origin, feeding method, water source, and education level of the farmers. Predictive factors like season, water sources, grazing pastures, and grazing systems are noted in Iran by Hajipour et al. (2021) and Rafiq et al. (2023). Predictive factors, such as season, water sources, grazing pastures and grazing systems, were reported in Iran by Hajipour et al. (2021) and Rafiq et al. (2023). Additional factors that affect outcomes include livestock origin (Tasse 2024), regional variation (Martinez-Ibeas et al. 2016), sex **(**Martindah et al. 2023) and rearing system **(**Sadarman et al. 2007). It was also found that the sampling location in Manokwari Selatan District was one of the significant predictive factors affecting paramphistomosis. Indeed, the high prevalence of paramphistomosis observed in this district is closely associated with the topography of the area and livestock management system. The region contains swamps, rice-paddy field vegetation with nearby irrigation systems, and parts of waterlogged mangrove forest. It makes perfect habitats with proper shelters, a breeding ground and a food supply for snails as intermediate hosts **(**Suhardono et al. 2006; Idris et al. 2018; Nugroho 2023). Moreover, the high prevalence is partly due to the traditional or extensive livestock production system. In this system, cattle are directly grazed in pastures, paddy fields, coconut plantations (Jamil et al. 2017) and the edges of swamps, puddles, and ditches for grazing (Nugroho 2023). Aquatic snails serve as intermediate hosts and are found in moist, waterlogged environments like paddy fields and mangrove forests. Therefore, there is a higher risk that livestock grazing in these regions will come in contact with infectious metacercariae that are attached to vegetation.

This study showed that the origin of the livestock was significantly different ($P<0.05$) with a higher prevalence recorded in cattle from own breeders (not purchased) than in cattle from purchased. These results are consistent with earlier research by Hajipour et al. (2021) and González-Warleta et al. (2013). This is because self-bred cattle have a higher cumulative risk of infection over time due to their ongoing exposure to the same environment, which may contain *Paramphistomum spp.* eggs.

The prevalence of paramphistomosis was also significantly ($P<0.05$) affected by the method of feeding cattle, with a higher prevalence observed in cattle that forage freely than the cattle fed the cut-and-carry method. This is consistent with a study by Rinca et al. (2019), that found cattle grazing on wet pastures and consuming rice straw had a higher prevalence of trematodes. Because *Paramphistomum spp.* metacercariae can attach to forage that has been cut too close to the ground, feeding untreated or undried forage can raise the risk of infection. To reduce the risk of parasitic infection, it is advised that forage be sun-dried for two to three days before being fed to livestock. Compared to livestock that graze freely, livestock reared in pens has a lower risk of trematode parasite infection (Zafar et al. 2019).

Cattle who drank from irrigation and rivers had a significantly higher prevalence of paramphistomosis than cattle who drank from wells. This result is consistent with a study conducted by Hajipour et al. (2021) that found increased incidences of Amphistomum infection in cattle who grazed in wetland areas and drank from rivers. This is because, according to Rolfe et al. (1991), open-water sources have a high potential for spreading infection, as irrigation and river systems are frequently contaminated by parasitic larvae and eggs derived from the feces of infected livestock or wild animals. Furthermore, freshwater snails are more frequently found in stagnant or slow-flowing aquatic environments, like rivers and irrigation, as intermediate hosts in the life cycle of *Paramphistomum spp.*, compared to well water that is sourced from underground and is more sterile (Mage et al. 2002; Rangel-Ruiz et al. 2003).

The prevalence of paramphistomosis in beef cattle was significantly impacted by farmers' higher educational levels. The prevalence of paramphistomosis was higher in cattle managed by farmers with lower levels of education. This result is in line with findings from Purwaningsih et al. (2018) and González-Warleta et al. (2013). Higher-educated farmers are more likely to implement efficient management techniques, such as consistent deworming programs, better sanitation and sensible grazing strategies (Purwaningsih et al. 2018). Meanwhile according to González-Warleta et al. (2013), highly educated farmers tend to be more aware of the transmission of paramphistomosis. Furthermore, farmers with lower education levels were more likely to have significant risk factors such as inadequate grazing management and the practice of mixing pens for livestock of different ages. This was also observed in Bangladesh and Ethiopia, where improved farming practices and knowledge were correlated with reduced prevalence of disease and intensity (Paul et al. 2011; Melaku and Addis 2012).

The total egg per gram (EPG) counts in feces were used to calculate the infection intensity in this study, and the results showed that the studied beef cattle had varying levels of infection. The pattern indicated that light to moderate infections were more common than severe infections. The average EPG count from this study was in line with findings from a study conducted in Bangladesh by Dey et al. (2022). This may be attributed to the high reproductive potential of adult *Paramphistomum spp*., which can survive in the host for several years (Dorchies 2006). Another contributing risk factor is the absence of regular deworming procedures among farmers. Typically, farmers only treat patients when they exhibit serious clinical symptoms. Albendazole, which is primarily used as a prophylactic treatment against nematodes and trematodes, but has little or no effect on *Paramphistomum spp.*, is the only board-spectrum anthelmintics that farmers utilize.

Conclusion

Epidemiological data indicate a high endemicity of paramphistomosis, with *Paramphistomum spp.* infection occurring in seven districts in Manokwari Regency, West Papua. The sampling location, livestock origin, feeding method, water sources and farmer education levels were the risk factors that together affected the prevalence of paramphistomosis. The spatial distribution of parasites between livestock host and intermediate host snail corroborates each other so that it can support the sustainability of parasite's life cycle. A comprehensive strategy is required to prevent and control paramphistomosis, which includes managing the environment, processing feed, managing water sources, and increasing farmer knowledge and education. This GIS map can serve as a guide to determine which regions are more vulnerable to paramphistomosis and need greater attention. Particularly regarding environmental factors as risk factors for paramphistomosis and its effect on livestock economics, further research is still required. The information provided here is intended to be used as a foundation for farm management modifications.

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Data Availability: All data that were evaluated during the research are available in the manuscript.

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