Global Evidence on the Seasonality of Enteric Infections, Undernutrition, and Livestock Ownership

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Livestock, Malnutrition, and Health

Exposure to livestock and poultry poses serious health risks for young children. This is driven primarily by proximity to soil and poultry feces in livestock-owning households. Livestock ownership is also associated with increased risk of exposure to cryptosporidium through shared water sources. Both pathways expose children to the fecal-oral contamination pathway, increasing risk of environmental enteropathy.

However, livestock also provides an important source of animal-source foods (ASFs), which are linked to improved child nutrition status. ASFs are rich in heme iron, which are readily absorbed by humans, as well as zinc, selenium, and other micronutrients. Evidence from Ethiopia, Kenya, and Uganda suggests that household livestock ownership has a slight beneficial effect on child stunting prevalence; however, the mechanisms of this effect are unclear.

Livestock and poultry thus have a concurrent limited protective effect on nutrition status through ASFs, and detrimental effect on health status through exposure to zoonotic pathogens and feces. This nexus presents several challenges to nutrition, health, and livelihoods.

Methodology

We investigated evidence for the livestock-disease-nutrition nexus in the US Agency for International Development's Demographic and Health Surveys (DHS). DHS data are nationally and often sub-nationally representative, and are conducted in five-year intervals, forming the largest collection of survey microdata in the world. Data on livestock ownership was collected from DHS Round 5 onwards, forming a relevant subset for this analysis.

Information on livestock ownership by type from the Household Recode was merged with Children's Recode dataset, which contained information about birth, anthropometry, disease, and ASF consumption for children under age five. Health indicators (binary indicators for diarrhea, and cough in two weeks preceding survey, and fever in the week preceding survey) were collapsed into one binary *sickness* variable. A Weight for Height Z-score (WHZ) below –2 was used to generate a binary variable for undernutrition.

A series of hierarchical logistic regression models were developed to evaluate effects individually and collectively.

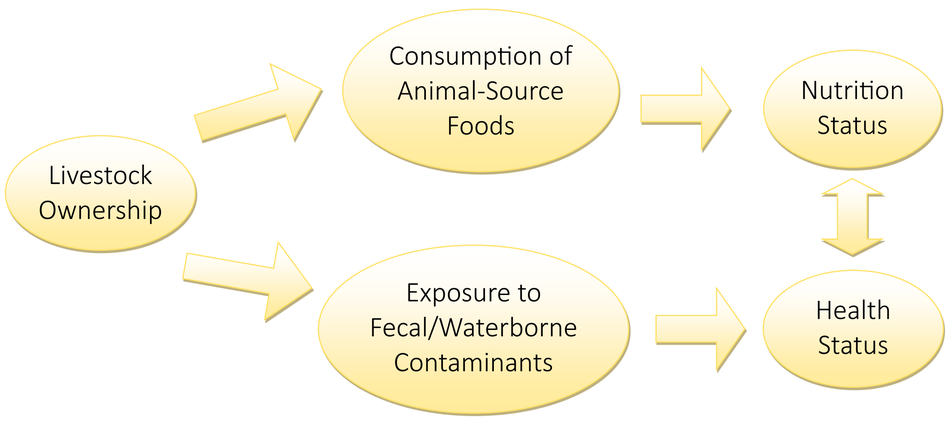
$$\text{Outcome} = \beta_f \text{Fowl} + \beta_p \text{Pigs} + \beta_h \text{Horses} + \beta_c \text{Cattle} + \beta_g \text{Goats or Sheep} + \beta_e \text{Eggs} + \beta_d \text{Dairy} + \beta_m \text{Meat} \; K_L + \delta_E + \Upsilon_{own} I_{own} + \Upsilon_{con} I_{con} + \varepsilon$$

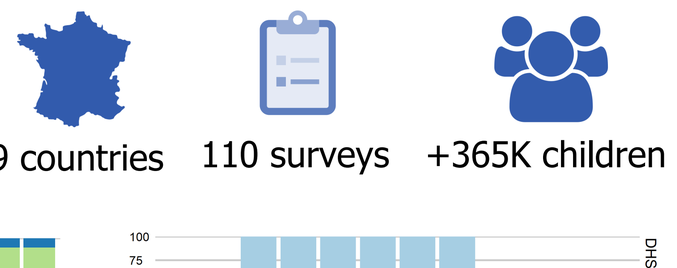
Where L: Communal livestock ownership by type

E: Survey Fixed Effects (DHS round, country, urban, child age and sex)

I_{own}: Interactions between types of livestock owned (e.g. poultry x goats)

I_{con}: Interactions between types of livestock owned and products consumed (e.g. poultry x eggs)





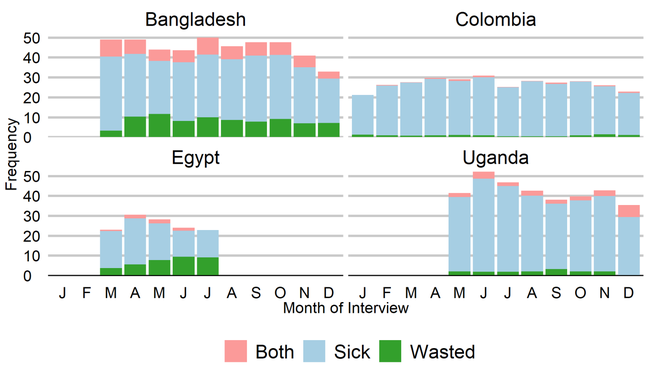


Fig. 1 | Prevalence of *sickness* (defined as presence of cough, fever, or diarrhea in the past two weeks), or *wasting* (defined as weight for height z score below –2 SD from reference), by Month of Interview and Country. The distribution of these phenomena vary significantly over space and time.

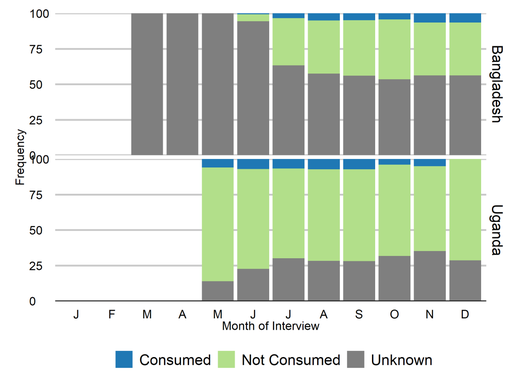


Fig. 2 | Consumption of Animal-Source Foods (dairy products, meat, fish, or eggs) in the past 24 hours by country and month of interview. Consumption frequency varies greatly by space and time.

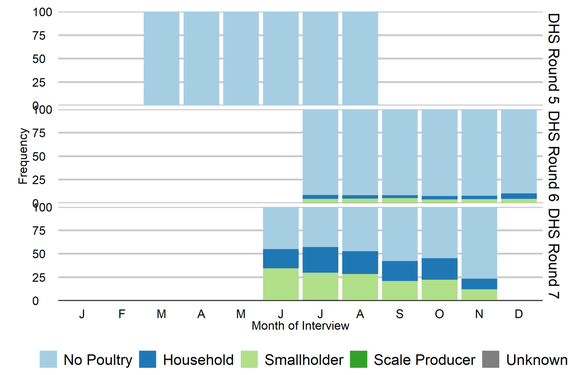


Fig. 3 | Poultry ownership in Bangladesh by DHS round and scale of operations. Poultry ownership is somewhat seasonal, as smallholders prefer to grow during summer months. Significant differences in poultry ownership are observed between DHS Round 6 (2011) and Round 7 (2014). This may be due to varying sampling locations, or local programs to boost value chains.

	Sickness	Undernutrition
Child's Age (months)	-0.013***	-0.010***
	(-0.0003)	(-0.0003)
Male	-0.020***	-0.100***
	(-0.007)	(-0.01)
Poultry/Fowl	0.001**	-0.002***
	(-0.001)	(-0.001)
Horses	-0.011**	0.011**
	(-0.005)	(-0.005)
Goat or Sheep	-0.001*	0.002***
	(-0.001)	(-0.001)
Communal Poultry/ Fowl	0.00005***	0.00001
	(-0.00001)	(-0.00001)
Communal Pigs	-0.001***	-0.0001
	(-0.0001)	(-0.0002)
Communal Horses	-0.0003***	-0.0001
	(-0.0001)	(-0.0001)
Communal Goats	0	0.00004***
	(-0.00001)	(-0.00001)
Communal Cattle	-0.00001	-0.0001***
	(-0.00002)	(-0.00002)
Egg Consumption	-0.035***	-0.02
	(-0.01)	(-0.013)
Meat Consumption	0.008	-0.077***
	(-0.009)	(-0.013)
Dairy Consumption	-0.029***	-0.018
	(-0.009)	(-0.012)
Observations	146,636	148,576
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 1 | Pooled regression results, truncated to show only significant covariates. Both household and community-level livestock ownership displays significance for both sickness and undernutrition outcomes. Eggs and dairy consumption are significantly related to adverse health outcomes, whereas meat consumption is significantly linked to undernutrition.

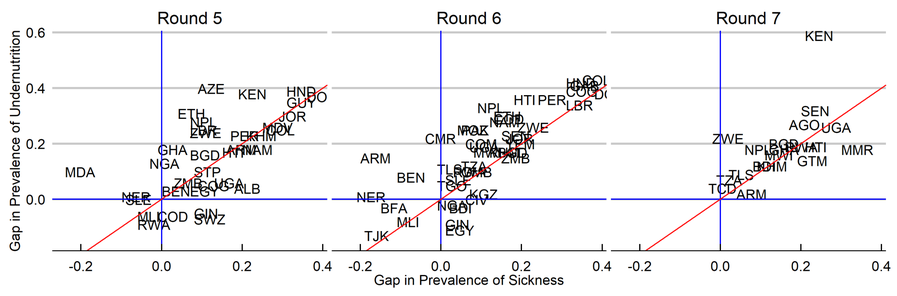


Fig. 4 | Gap in prevalence of sickness and undernutrition between the 1st and 5th wealth quintiles of sample by country. Wealth allows for consumption smoothing to avoid both adverse outcomes. Large gaps between wealth quantiles is indicative of large disparities in health and nutrition status across the population.

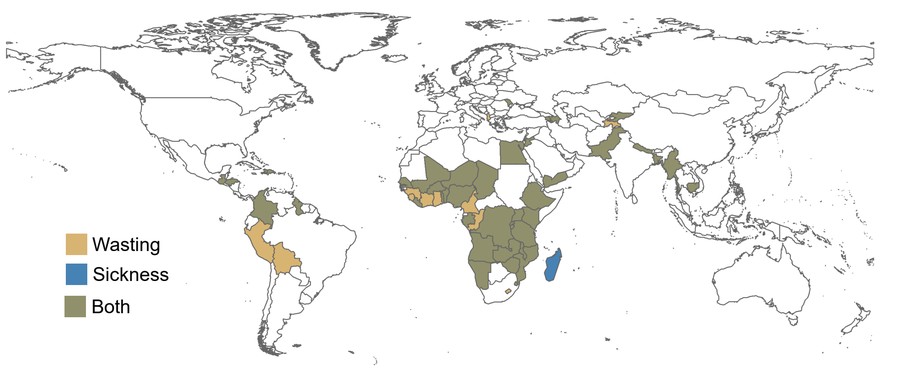


Fig. 5 | Countries where month of interview is a significant predictor of wasting and/or sickness, after controlling for livestock ownership and animal-source food consumption. In most African and Asian countries, health and nutrition outcomes depend strongly on time of year. This is closely aligned with climatological phenomena, which influence the onset of the lean season.

Covariate	Sickness	Undernutrition
Cattle	0.54	0.58
Goats or Sheep	0.81	0.72
Horses	1.02	0.54
Pigs	1.20	0.64
Poultry/Fowl	1.00	1.04
Dairy	0.92	0.70
Eggs	0.89	0.65
Meat	0.81	0.90

Table 2 | Average odds ratios for sickness and undernutrition, predicted by livestock ownership and ASF consumption across countries.

Covariate	Eggs	Dairy	Meat
Cattle	0.83	1.34	0.88
Goats or Sheep	1.18	0.80	0.77
Horses	0.35	157.71	0.88
Pigs	0.81	0.72	0.97
Poultry/Fowl	0.78	0.95	0.90

Table 3 | Average odds ratios for ASF consumption by type of livestock owned across countries.

As seen in Table 1, both household and communal livestock ownership are significant predictors of sickness and undernutrition. However, livestock ownership does not directly imply increased ASF consumption. As seen in Table 3, only cattle ownership is linked to increased likelihood of dairy consumption. The effect of goats or sheep on eggs, and the effect of horses on dairy, indicates that owning either of these species can improve income, thereby allowing for improved purchase of ASFs for consumption. These differences are reflected in the average country-level odds ratios presented in Table 2. These results indicate that ownership of horses, pigs, and poultry/fowl are linked to a greater likelihood of sickness, and ownership of poultry is linked to greater likelihood of undernutrition, specifically wasting.

Conclusions

- Month of Interview is an important control in assessments of health and undernutrition. Effects are not salient in pooled regressions, but country-level analyses indicate that interview month is a significant predictor of ASF consumption and livestock ownership.
- Community-level livestock ownership ($\Sigma L_{l,r}$) displays significance in both whole dataset– and country-level analyses. This suggests that malnutrition and adverse health outcomes may be driven by environmental factors rather than household-level factors.
- There is high spatial, temporal, and demographic heterogeneity in ASF consumption and livestock ownership. Explanatory models must account for variability across space, time, and populations.

Next Steps

Exploratory logistic regression models confirm the importance of livestock ownership in assessing health and undernutrition outcomes. The quality of this analysis can be improved by utilizing Bayesian methods to address hierarchical nested conditional probabilities and controls. Bayesian methods can also provide robust confidence intervals necessary to assess the strength of livestock ownership as an intermediary variable. Given the significance of the month of interview, harmonic regression methods can also be applied to improve understanding of seasonality across various spatial scales. Harmonic methods can provide robust results for regions with limited sampling periods during the year, and help elucidate temporal patterns in ASF consumption and livestock ownership at the country and continental scales. DHS data is additionally limited by the 24-hour recall period for food consumption data, compared to the two-week reporting period for cough, fever, or diarrhea. These data can be supplemented with data from the United Nations Children's Fund Multi-Indicator Cluster Survey, and the World Bank's Living Standards Measurement Surveys. Both these databases provide similar high-resolution survey data, with additional questions about consumed foods over various recall periods. These datasets can also provide significant insight into livestock-based production and sales decisions at the household level which affect food security, health, and nutrition status.

REFERENCES | **Humphrey**, J. H. (2009). "Child undernutrition, tropical enteropathy, toilets, and handwashing." Lancet 374: 1032-1035. | **Mosites**, E. M., P. M. Rabinowitz, S. M. Thumbi, J. M. Montgomery, G. H. Palmer, S. May, A. Rowhani-Rahbar, M. L. Neuhouser and J. L. Walson (2015). "The Relationship between Livestock Ownership and Child Stunting in Three Countries in Eastern Africa Using National Survey Data." PLoS One 10(9): e0136686. | **Ngure**, F. M., B. M. Reid, J. H. Humphrey, M. N. Mbuya, G. Pelto and R. J. Stoltzfus (2014). "Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: making the links." Ann N Y Acad Sci 1308: 118-128. | **Marshak**, A., H. Young, E. N. Bontrager and E. M. Boyd (2017). "The Relationship Between Acute Malnutrition, Hygiene Practices, Water and Livestock, and Their Program Implications in Eastern Chad." Food Nutr Bull 38(1): 115-127.

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