HHS Public Access
Author manuscript
Food Secur. Author manuscript; available in PMC 2017 June 01.

Published in final edited form as:
Food Secur. 2016 June ; 8(3): 507–520. doi:10.1007/s12571-016-0579-5.

Sustainable smallholder poultry interventions to promote food security and social, agricultural, and ecological resilience in the Luangwa Valley, Zambia

Sarah E. Dumas[1,2], **Luke Lungu**[3], **Nathan Mulambya**[3], **Whiteson Daka**[3], **Erin McDonald**[1], **Emily Steubing**[1], **Tamika Lewis**[1], **Katherine Backel**[1], **Jarra Jange**[4], **Benjamin Lucio-Martinez**[4,§], **Dale Lewis**[3], and **Alexander J. Travis**[1,2,*]

[1]Baker Institute for Animal Health, Cornell University, Ithaca, NY 14853

[2]Atkinson Center for a Sustainable Future, Cornell University, Ithaca, NY 14853

[3]Community Markets for Conservation (COMACO), Wildlife Conservation Society, Manda Hills, Lusaka, Zambia

[4]Department of Population Medicine and Diagnostic Sciences, Cornell University, Ithaca, NY 14853

Abstract

In Zambia's Luangwa Valley, highly variable rainfall and lack of education, agricultural inputs, and market access constrain agricultural productivity, trapping smallholder farmers in chronic poverty and food insecurity. Human and animal disease (e.g. HIV and Newcastle Disease, respectively), further threaten the resilience of poor families. To cope with various shocks and stressors, many farmers employ short-term coping strategies that threaten ecosystem resilience. Community Markets for Conservation (COMACO) utilizes an agribusiness model to alleviate poverty and food insecurity through conservation farming, market development and value-added food production. COMACO promotes household, agricultural and ecological resilience along two strategic lines: improving recovery from shocks (mitigation) and reducing the risk of shock occurrence. Here we focus on two of COMACO's poultry interventions and present data showing that addressing health and management constraints within the existing village poultry system resulted in significantly improved productivity and profitability. However, once reliable productivity was achieved, farmers preferred to sell chickens rather than eat either the birds or their eggs. Sales of live birds were largely outside the community to avoid price suppression; in contrast, the sale of eggs from community-operated, semi-intensive egg production facilities was invariably within the communities. These facilities resulted in significant increases in both producer income and community consumption of eggs. This intervention therefore has the potential to improve not only producers' economic resilience, but also resilience tied to the food security and physical health of the entire community.

[*]Corresponding author: ajt32@cornell.edu, phone: 1-607-256-5613, fax: 1-607-256-5608.
[§]In memory of Dr. Benjamin Lucio-Martinez who was an important contributor to this work.

Keywords

Animal-source food; Conservation farming; Food security; Poultry; Resilience; Smallholder farmers

Introduction

USAID defines resilience as "the ability of people, household, communities, countries, and systems to mitigate, adapt to, and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth" (USAID 2013). Smallholder farmers in developing countries rely on the complex interaction of social, ecological, and agricultural systems to craft livelihood strategies and achieve advantageous livelihood outcomes (e.g. food security, freedom from poverty). As such, they are extremely vulnerable to both long-term trends (e.g. climate change, land and resource degradation, endemic diseases, and population growth) and unexpected shocks (e.g. droughts, floods, market shocks, and political or ethnic conflicts). These stressors and shocks challenge their resilience, both in terms of their ability to maintain their often low-level equilibrium (chronic poverty and hunger) and their capacity to transition to a higher-level equilibrium (improved food security, income, health, and wellbeing; Barrett and Constas 2014).

In Zambia's culturally and linguistically diverse Luangwa Valley, smallholder farmers have long faced social, economic, ecological, and agricultural stressors and shocks that reinforce their chronic poverty and food insecurity. This situation has worsened in recent decades because of a growing population, inadequate social, market, and physical infrastructures, human and animal disease, widescale natural resource degradation, and increasing economic reliance on highly volatile cash crops (Lewis et al. 2011). Together, these factors force households (HHs) to use short-term coping strategies such as unsustainable charcoal production or wire snaring of game, which reduce future economic opportunities as they further deplete valuable resources. For more information on regional vulnerabilities to agricultural production and human health and wellbeing, please see Online Resource 1.

The economic and social dependence of farming HHs on an underperforming agricultural system and rapidly diminishing natural resource base emphasizes the importance of recognizing the region as a *system*. This underscores the strong synergistic relationship among *ecological resilience*, the capacity of an ecosystem to absorb perturbation and maintain identity and function, *agricultural resilience*, the capacity of a farming system to maintain optimal productivity in the face of disturbances, and *social resilience*, the ability of a community or HH to maintain an upward trajectory out of poverty in the face of a myriad of stressors and shocks (Adger 2000, Barrett and Constas 2014). In other words, the social resilience of a smallholder farming HH is instrumentally linked to the resilience of the underlying natural resource and agricultural subsystems (Barrett and Constas 2014).

Focusing on these interacting relationships, Community Markets for Conservation (COMACO) has taken a holistic systems approach to promote social, ecological, and agricultural resilience in the Luangwa Valley (Lewis et al. 2011). With over 89,100 farmer members over 77,000 km^2, COMACO utilizes a business model to maximize farmer profits.

COMACO operates over the full spectrum of a vertically-integrated value chain, from training farmers in methods of conservation farming (CF), to purchasing surplus farm products from smallholder farmers at their 259 community bulking centers, to transporting them to community trading centers for consolidation and sale into the commodities market or processing into value-added products. Profits generated are passed back to member farmers in the form of premium commodity prices and 'conservation dividends' (cash or in-kind payment for achieving conservation targets). Training and support in alternative income-generating activities such as poultry production, bee-keeping, and carpentry further mitigate the effect of any one perturbation on a HH or community. Training is disseminated through a network of 3935 producer groups and their 1650 volunteer lead farmers and is aggregated in a COMACO publication for their farmers, called "Better Life Books." Additionally, over 1000 hand-powered radios have been distributed to lead farmers, and producer groups gather twice weekly for the COMACO Farm Talk radio program, which provides instruction and reinforces CF techniques.

COMACO farmers have adopted 40-90% of individual CF techniques (Lewis et al. 2011), with overall adoption of 67% in 2011 (COMACO 2014). The use of CF was associated with a 50% increase in maize yields, 37% increase in groundnut yields, and 40% increase in soybean yields compared to traditional methods, with increasing yields each year (COMACO 2014). Approximately 50% of farmers practice crop diversification, growing three or more food crops in 2013. One of COMACO's newest interventions, a seed reserve program, allows farmers to improve disease resistance on their farm by diversifying plant genetics and reestablishing their fields in event of crop loss. In the 2012-2013 season, 11,200 farmers contributed seeds to the reserve, which currently totals 228 tons. As a result of these improvements in the agricultural system, average annual income in COMACO-member HHs has more than doubled since 2009 (COMACO 2014).

Purpose and objectives

The objective of this paper is to investigate the impact of targeted interventions promoting village-level poultry production on the resilience of both the local poultry system and smallholder farming HHs in the Luangwa Valley. We evaluated three key parameters of the interventions targeting *village chickens*: (1) average HH flock size over time and across seasons; (2) average HH profitability; and (3) family consumption of chicken meat and eggs. Parameter 1 is an indicator of poultry system (agricultural) resilience, while parameters 2 and 3 are indicators of the program's impact on HH resilience. For the intervention targeting *semi-intensive egg production*, we evaluated four parameters: (1) facility productivity; (2) profitability and contribution to overall HH income; (3) impact on average HH consumption of eggs in participating HHs; and (4) impact on egg consumption in surrounding communities. Parameter 1 is a measure of agricultural resilience; parameters 2 and 3 are measures of HH resilience in participating HH. As a proxy for dietary quality, parameter 4 is a measure of the program's impact on HH resilience in the surrounding community.

First, we provide data showing that addressing health and management constraints within the extensive village poultry system resulted in improved resilience of the poultry system, as measured by significantly improved flock productivity. The intervention affected HH resilience through increased poultry profitability, but not through increased consumption of poultry meat or eggs in participating HHs. We next provide data showing that the establishment of community-operated, semi-intensive egg production facilities was highly profitable for producers and increased HH consumption of eggs in the communities surrounding the egg facilities, but not in the producing HHs themselves. This suggests that semi-intensive egg production may contribute to the social resilience of participating HHs through increased incomes; it additionally suggests that this intervention has the potential to improve HH resilience in the surrounding community through improved nutrition and physical health.

Methods

Study site

This research took place in the Mambwe and Lundazi districts, which are located in Zambia's Eastern Province and have populations of 68,918 and 323,870 people, respectively (CSO 2009). Each district is further subdivided into wards, or Chiefdoms. The western border of both districts is defined by the Luangwa River, which runs along the southeastern edge of the South Luangwa and North Luangwa National Parks, home to large populations of wildlife. The average HH is composed of seven people, 2.4 of whom are children under the age of 16. Fifty-four percent of heads of HH have a maximum education level of primary school (grade seven) or less. The average net HH income in the 2009-2010 farming season was $450, with 75% of earnings generated through crop production (Ngumayo 2011). An estimated 90% of HHs in the Luangwa Valley rely on agriculture as their primary income generating activity (COMACO 2014).

Conceptual framework

The hypothesized mechanisms by which COMACO's programs affect resilience in the Luangwa Valley are captured in the conceptual framework (Figure 1). This framework illustrates that HH resilience is fundamentally linked to the resilience of the agricultural and ecological subsystems on which smallholders depend. COMACO's activities therefore aim to enhance HH resilience *directly* and *indirectly* – through the promotion of agricultural and ecological resilience – using multiple complementary mechanisms. Improved farming practices, farmer education, soil improvements, and seed storage promote agricultural resilience, as measured by annually increasing yields and decreasing farm relocation. These programs also increase HH income through premium crop prices, increased yields, and conservation dividends, which in turn promotes HH resilience by enabling increased expenditures on farming inputs, higher quality food, health care, and education. Two key indicators of social resilience in this context, then, are (1) increasing HH incomes, and (2) improving food security, defined as ‘[having] physical, social, and economic access to sufficient, safe, and nutritious food that meets [one's] dietary needs and food preferences for an active and healthy life’ (UNSCN 2010). In turn, income and food security theoretically promote ecological resilience by decreasing HHs’ routine, seasonal, and urgent reliance on wildlife and natural resources, including poaching, carbon release through residue burning, charcoal production, and clearing of forested areas for plot relocation.

Support of alternative income-generating activities further encourages HH resilience by mitigating the impact of perturbations to the cropping system (such as crop loss or market fluctuations), thereby building adaptive capacity. Livestock interventions are a particularly promising approach to advancing HH resilience because of their potential to both diversify incomes and directly improve community food security and nutritional status through consumption of locally-produced animal source foods (ASF). ASF, such as meat, milk, and eggs, are rich in nutrients critical for growth and cognitive development. Yet, for children of poor farmers in the Valley, ASF consumption is limited by poor livestock productivity due to endemic infectious diseases, poor quality forages, and poor access to improved breeds and veterinary care. COMACO's poultry program aims to promote the resilience of poultry systems (as measured by losses, flock size, productivity, and profitability) by addressing the constraints to extensive poultry production (village chickens) and egg production (semi-intensively raised layers).

Interventions in extensive poultry system

Improved management—The primary constraints to poultry production were identified through focus groups and key informant interviews from 2006 to 2007 (McDonald, Lewis and Travis, unpublished data). Community poultry production groups consisting of 10 to 15 farmers each were formed to facilitate the implementation of interventions. Extension workshops targeted the management constraints identified during formative research, including the building of elevated chicken houses and providing fresh water and supplemental feed.

Newcastle disease vaccination—Based on the description of flock losses and post-mortem examination of dead birds, Newcastle disease (ND) was identified as the primary constraint in village poultry production (McDonald, Lewis and Travis, unpublished data). Two community vaccinators were selected from each area, and partners from the International Rural Poultry Centre trained selected community vaccinators following a training manual created by the International Rural Poultry Centre and COMACO (2007). These training sessions were repeated annually, led by students from the Cornell University College of Veterinary Medicine and COMACO extension staff.

A thermostable, live, freeze-dried vaccine, ND ‘V4 HR’ (Malaysian Vaccines & Pharmaceuticals, Kuala Lumpur, Malaysia), was maintained at a central location in a refrigerator, then transported in cool boxes to vaccinating areas at the start of each campaign. The vaccine was diluted and administered via eyedrop following the manufacturer's instructions. Farmers paid approximately $0.05 per vaccine dose, and vaccinators were paid a base allowance plus performance-based pay of 70% of generated revenue. A vaccination campaign was performed every July, November, and April. Each vaccinator was given Household Vaccination Forms on which to record each participating farmer, the number of birds owned and vaccinated, and payment made. They also documented any significant die-offs reported in the preceding three months.

Impact assessment—Adoption of ND vaccination was assessed through continuous monitoring of the number of birds vaccinated and number of HHs participating, as recorded by the vaccinators in the Household Vaccination Form during the vaccination campaigns from 2007 to 2011. The total number of poultry-owning HHs was estimated from Zambia's 2010 census, which counted the number of HHs in each of Mambwe district's Chiefdoms (CSO 2009), with an assumed 80% of HHs raising poultry (Songolo and Katongo 2001). To investigate the adoption of improved poultry housing and its impact, we conducted a structured survey of 59 HHs in July 2011. In each of three Chiefdoms, a village was selected based on accessibility, and every HH within that village was surveyed. Due to the small size of these villages, in each case a neighboring village was also surveyed until 20 HHs were evaluated per Chiefdom.

To monitor the impact on flock sizes, community vaccinators documented HH flock size every four months at the time of vaccination. The effect of poultry production on HH income was assessed in a longitudinal survey conducted at 130 participating HHs in four Chiefdoms by seven community vaccinators during the 2011-2012 season. At each visit, the vaccinator counted the number of chickens and interviewed the head of HH to determine the number of eggs and chickens eaten and sold in the past month and at what price, and the number of losses of chickens and eggs in the past month. These data were compared to those from an independent survey of 893 HHs in the Luangwa Valley conducted by the Luangwa Valley Ecosystem Partnership Management Initiative, which includes data on the annual income generated through poultry and egg sales in the 2009-2010 season (Ngumayo 2011). The latter survey includes information from both COMACO and non-COMACO farmers, allowing comparison of poultry incomes for HHs participating in the program with all poultry-owning HHs in the region.

The 2011-2012 longitudinal survey data were also used to determine the impact of the interventions on family chicken and egg consumption. An additional cross-sectional survey of 121 HHs in three Chiefdoms was conducted in February 2012; it includes data on household egg and meat consumption in both participating and non-participating HHs. Finally, six focus group discussions were held in the Chiefdom of Mnkhanya to discuss the motivations for rearing poultry and determinants and barriers to home consumption of poultry meat and eggs. Focus groups were held in the months of January and February 2012; each discussion consisted of between 8 and 15 people, with a total of 66 producers participating.

Semi-intensive egg production intervention

To test the economic feasibility and acceptability of a semi-intensive egg production project, three pilot facilities were constructed in June 2010 in three different Chiefdoms, each operated by a single farmer. Each farmer was provided with 10 (facility 1) or 20 (facilities 2 and 3) hybrid layer hens at the point-of-lay (20 weeks) through an interest-free loan. The costs associated with construction of the facilities were borne completely by the farmer. They received training on flock management, nutrition, hen health, egg collection, and record keeping, and their progress was checked monthly by the COMACO Poultry Extension Officer. The operator of each facility was asked to maintain daily records on the total number of eggs collected, number of eggs consumed by the family, number of eggs sold and price of each egg, and the amount and cost of feed purchased, and their records were monitored from July 2010 to May 2011. A semi-structured in-depth interview conducted after 11 months of operation assessed the market demand, their use of the income generated by the facility, and the perceived impact on family welfare. This interview was conducted in English (SED) with translation to Chinyanja by the COMACO Poultry Manager (LL).

To investigate the nutritional impact of the pilot layer facilities on the surrounding community, the 20 HHs nearest to each facility (60 total HHs) were surveyed 11 months after the initiation of the project (June 2011). The head of HH was asked to describe the HH demographics, current egg consumption patterns, and estimated egg consumption patterns prior to the installation of the layer facility in their area. This level of consumption was then compared to that of 60 HHs in three matched control areas, where village chickens, road-side stalls, and shops were the only sources of eggs. Because no baseline data were collected on their prior consumption patterns, each facility owner was asked to approximate the average number of eggs consumed by the family per month in the year prior to the initiation of the project.

The details of each data collection method for both the extensive and semi-intensive poultry programs can be found in Online Resource 2. All survey instruments and forms are available from the author on request. All data were analyzed using non-parametric tests (Kruskal-Wallis or Wilcoxon Rank Sum; JMP Pro Version 11.0, Copywrite ©2013 SAS Institute Inc.).

Results

Improvements in extensive poultry system

Table 1 summarizes the adoption of recommended strategies for village poultry production and indicators of their impact four years after initiation of the interventions.

Adoption of recommended strategies—As of 2011, 395 poultry production groups had been formed consisting of 3265 women and 2006 men, or an estimated 21% of the district's poultry-owning population. From July 2007 to November 2011, the ND vaccination program grew 236% in terms of the number of birds vaccinated, and 50% in the number of participating HHs. Using 2010 Census data, we estimate that this was still less than 3% of poultry-raising HHs in the district.

Impact on flock productivity—In a 2011 sample of all poultry-owning HHs, 71.2% used the elevated housing-type promoted by the program. Farmers using the elevated housing type had significantly larger flock sizes (mean 20.4 birds) compared to those using ground housing (11.0 birds) or housing the birds in the family home (11.4 birds; Kruskal-Wallis, p-value for trend= 0.018). They also reported significantly fewer flock losses over the past three months as a fraction of current flock size (elevated houses= 0.299, grounded houses= 0.684, family house= 0.549; Kruskal-Wallis, p-value for trend= 0.0009).

We found an increase in the average number of adult birds owned by farmers participating in the vaccination program compared to HHs in control areas (Figure 2). Inconsistent collection of data due either to temporary funding constraints or heavy flooding and impassable roads makes statistical interpretation of possible trends of growth over time difficult. However, due to recurrent and marked seasonal fluctuations in flock sizes, it is informative to compare average HH flock sizes during the same months prior to and after intervention. There was a significant increase in the average HH flock size in vaccinating HHs from July 2007 (mean 10.9 birds) to July 2011 (mean 25.7 birds; Wilcoxon Rank Sum, $p < 0.0001$) and from November 2007 (mean 17.8 birds) to November 2011 (mean 28.3 birds; Wilcoxon Rank Sum, $p < 0.001$).

Impact on poultry profitability—A 2001 survey in the Luangwa Valley found that poultry production contributed an average of only $16.89 per year (Lewis et al. 2001, adjusted for inflation to 2011 value). After interventions, a survey following 130 participating HHs through the 2011 – 2012 production season found an average $40.25 annual income from poultry production, a 138% increase in poultry profitability. In comparison, an independent survey of 893 HHs found that the average poultry-owning HH in the Luangwa Valley, including those that did not participate in COMACO programs, made $27.83 from the sales of chickens and eggs in the 2009 – 2010 farming season (Ngumayo 2011), a 65% increase in their annual profits from poultry production since 2001. This demonstrates that although poultry producers across the region saw an increase in poultry income, participants in the COMACO program realized substantially greater profits.

Impact on family ASF consumption—The same longitudinal survey following 130 COMACO poultry farming HHs through the 2011-2012 farming season found that an average of 0.55 chickens were eaten/HH/mo. A separate 2012 cross-sectional survey of 121 HH found that families in the study area ate an average of 1.74 meals/mo containing chicken (where one bird is typically consumed over two family meals). These data suggested that although flock size went up significantly, HHs were not consuming the birds or eggs. Instead, focus group discussions revealed that producers preferred to sell birds; similarly, rather than eat eggs at home, they preferred to allow the eggs to hatch in order to have more adult birds to sell in the future. This notion become more evident in February 2012, when COMACO poultry producers began to set up markets to intensify the sale of birds to individuals outside the community (Dumas, personal observation).

Semi-intensive egg production

In response to the finding that increased flock sizes in the expansive poultry system had no impact on HH poultry or egg consumption, alternative poultry development interventions were explored to promote improved community nutrition through increased ASF consumption. The idea that gained the most support among COMACO staff and poultry producers was the establishment of small-scale egg production facilities to be operated by individual households or small groups. We proposed that this model would be consistent with the business-minded approach to poultry production that our farmers were taking, but would benefit community nutrition because the primary buyers would be their neighbors. Additionally, because eggs are a small and relatively inexpensive form of ASF, even poor families are able to regularly purchase them.

Profitability and acceptability—Over the first 10 full months of production, daily egg collection records revealed an average monthly production of 22.4 eggs/hen, with no significant difference among the three facilities (data not shown; one-way ANOVA, p= 0.694). The layer hens performed adequately, with 74.5% average production efficiency over the year (percentage of hens laying an egg on any given day). The gross income generated by facilities 1, 2, and 3 averaged $36.54, $72.25 and $66.21 per month, respectively. There was no statistically significant difference between the gross monthly income generated by facilities 2 and 3 (t-test, p=0.303), whereas the significantly lower profits in facility 1 were due to having only 10 layers instead of 20. After deducting the cost of feed and repayment of the loan for the hens, the annual net income for each facility was $113.03, $247.38 and $74.93 (facilities 1, 2 and 3, respectively).

Farming was the only source of income for the HHs owning facilities 1 and 3; those layer facilities resulted in a 58.3% and 54.2% increase in total net HH income, respectively. The head of HH for facility 2 had additional off-farm employment as a safari driver ($103 monthly); that facility therefore resulted in a 19.7% increase in total net HH income. In the year-end interview, all facility owners reported high demand for eggs. The income generated from the layer facilities was primarily used for school fees, uniforms, and supplies by all three owners. The remainder of their poultry income was used to pay for food items, such as cooking oil and salt, or home-improvements. All three perceived their family's lives to be greatly improved compared to the previous year, and all three planned to reinvest in new layer hens to continue production.

Impact on local egg consumption—The community surveys found that most of the HHs (89%) in both egg-producing and control areas consumed eggs regularly but infrequently. The 60 HHs surveyed around the layer facilities consumed a mean of 22.5 eggs/HH/mo compared to an estimated 13.3 eggs the year previously (Wilcoxon Rank Sum, p= 0.0033) and 12.6 eggs/HH/mo in control areas (Wilcoxon Rank Sum, p= 0.0046; Figure 3A). All HHs reported sharing eggs equitably within the family, and the traditional taboo against women and children eating eggs common in some parts of Zambia was not practiced in any HH sampled. In all three producer HHs, the number of eggs eaten per family per month (overall F-test controlling for facility, $p < 0.0001$) and per person per month (overall F-test controlling for facility, $p < 0.0001$) was significantly increased after the installation of the layers (Figure 3B). Notably, however, producer families continued to consume significantly fewer eggs per month than their neighbors (13.4 eggs/HH/mo in producer HHs vs. 22.5 eggs/HH/mo in neighboring HHs, F-test controlling for facility area, p= 0.0290) and the same as HHs from control areas (13.4 eggs/HH/mo in producing HHs vs. 12.6 eggs/HH/mo in control HHs, F-test controlling for facility area, p= 0.7877), suggesting that they considered egg production to be primarily an income-generating activity rather than a source of HH food.

Discussion

Impact of improvements in extensive poultry system

Although we documented high participation in poultry production groups, participation in the ND vaccination program was low, representing only 3% of poultry owning HHs in the district. Similarly, while the program grew substantially in the number of birds vaccinated, the number of participating HHs increased more slowly over the four years of the program. Because reports from COMACO extension officers and personal observation suggest high community demand for the vaccine and support of the program, these trends reflect the limited roll-out of the program over a small part of the COMACO operational area. New machinery currently being brought online at COMACO's main processing facility in Chipata will enable COMACO to take advantage of hundreds of tons of by-product and waste from their processing efforts to produce pelleted poultry feed. This should more tightly link the ND vaccine campaign and COMACO's business model moving forward, as is reflected in their 2014 strategic plan (COMACO 2014).

Warranting this expansion of the program, we show that the resilience of the extensive village poultry production system was significantly enhanced through ND vaccination and modest improvements in husbandry, as measured by fewer flock losses and increased average HH flock sizes. As proposed in Figure 1, improved poultry production can promote smallholder HH resilience through a number of mechanisms: (1) increased HH income; (2) diversification of HH income, making them more resilient to unexpected shocks and trends affecting crops (adaptive capacity); (3) increased food security as a result of improved access to poultry meat and eggs; and (4) indirectly (and more long-term) through improved ecological resilience as a result of decreased dependence on wildlife and natural resources to cope with shocks affecting cropping systems. Our research explored the association between HH resilience and the resilience of the poultry subsystem through linkages (1) and (3) only. Our data support the hypothesis that simple interventions in the backyard poultry systems would result in increased HH income. However, the data did not demonstrate any association between the interventions and consumption of poultry meat and eggs *by the producers*. This suggests that improvements in backyard poultry production did not have any direct effect on HH food security, though it might have unmeasured *indirect* effects for producing HHs on their own food security through increased food expenditures, income diversification, and ecological resilience.

The substantial increase in flock sizes and the profitability of poultry after only four years of intervention is consistent with other studies of ND vaccination in village chickens (Harun et al. 2009, Mgomezulu et al. 2009, Harrison and Alders 2010). However, despite increased flock sizes, families in our sample reported eating only a modest amount of village chickens and eggs produced by their village chickens. Although no baseline dietary information is available for comparison, the per capita consumption of poultry in Zambia is 3.1 kg/yr (FAO 2012) compared to < 1 kg/yr in our sample. Similarly, the average Zambian eats approximately 62 eggs/yr (Speedy 2003, FAO 2012), compared with only 34.1 eggs/yr in our sample of HHs without an egg production facility in their community. Taken together, these findings indicate that despite larger flock sizes resulting from our intervention, farmers in this study consumed far less poultry and eggs than the national average, which was itself far below the global average (Speedy 2003).

There are two likely explanations for this finding. First, prior to intervention, smallholder poultry farmers reported that the most common reason/time to consume a chicken is when it was showing signs of disease or had just died (Bagnol 2007). As flock morbidity and mortality were reduced through vaccination and improved husbandry, eating chickens increasingly required the slaughter of a healthy bird—a difficult adjustment. Second, in follow-up focus group and surveys, farmers reported that they preferred to sell birds rather than slaughter them for home consumption, suggesting that once production became reliable, they considered poultry production to be chiefly an income-generating activity. Poultry income was primarily used to pay for school supplies, medical fees, or HH items. Healthy chickens were consumed only on special occasions, such as to feed a visitor or holidays. They also reported infrequently eating eggs that the hens produce, preferring to let them hatch to increase flock size.

Other research examining the effect of livestock production interventions on HH dietary quality have found conflicting results, and two reviews have concluded that there is no evidence supporting the hypothesis that improved HH livestock production is associated with improved nutritional status in the producing HH (Leroy and Frongillo 2007, Masset et al. 2012). A review of the impact of smallholder livestock development on human nutrition found that although interventions can improve the productivity of livestock, slaughtering animals for home consumption remains infrequent and that ‘a significant share, if not most, of the production will be sold rather than consumed on-farm’ (Randolph et al. 2007), a conclusion that is consistent with our data.

Impact of semi-intensive egg production

In contrast, the results of the egg layer pilot program supported the hypothesis that semi-intensive egg production could impact social resilience through both a substantial increase in income for producer HHs and a significant increase in community consumption of ASF. The layer hens performed well, even in the extremely variable climate of the Luangwa Valley. The facilities had a meaningful impact on the overall HH income for the producers, giving them an economic incentive to continue production. The impact of the layer facilities on the community consumption of eggs was staggering, with the average person in a village surrounding a facility consuming as many eggs per year (66.6 eggs/yr) as the average Zambian (62 eggs/yr; Speedy 2003), and far in excess compared to controls that same year. (Calculation based on total number of eggs eaten/HH, divided by total number of individuals/HH, assuming equal distribution of eggs among all members of the HH. Means per month were then multiplied by 12 to get yearly consumption.)

The potential impact of livestock interventions on social resilience through improved nutritional status has not been well explored in the literature. Numerous studies have shown that feeding ASF to children increases physical growth, cognitive development, immune function, and school performance among undernourished children in developing countries (Neumann et al. 2002, Allen 2003, Whaley et al. 2003, Randolph et al. 2007, Allen 2012). These in turn impact an individual's ability to contribute productively as an adult to her community and national economy (Figure 4). Compared to plant foods, ASF contain more iron, zinc, vitamins A, D and E, riboflavin, and amino acids; ASF are the *only* source of vitamin B12. These nutrients also tend to be more bioavailable from ASF compared to plant-based sources. Yet, the barriers to ASF consumption in rural Zambia are significant, including cost, lack of local access, food safety concerns in the absence of a reliable cold-chain, and lack of caregiver awareness about ideal feeding practices. Eggs are inexpensive compared to other forms of ASF, making their regular consumption more affordable. Importantly, even in tropical climes, they require no cold-chain for up to a month if properly stored. Results presented here suggest that local production of eggs in a semi-intensive production system has the potential to sustainably provide poor rural families with a fresh, safe, low-cost form of ASF. Further research will explore the effect of this increased access and consumption on child nutritional status and community resilience. It should be noted that the pilot program did not contain a nutrition education component, a characteristic previously found to increase ASF consumption in livestock development interventions (Leroy and Frongillo 2007). Future expansion of village-scale egg layer production will be integrated with a nutritional education program.

Finally, it is notable that although two of the initial owners of the pilots were men, in both cases, their wives took over management and financial responsibility of the facility. This indicates that owning and operating an egg laying facility is a socially acceptable livelihood activity for women. Worldwide, women and girls are most at risk for extreme poverty. This, combined with the fact that targeting women as the beneficiaries of agricultural interventions has been shown to have the greatest impact on family nutrition (Leroy and Frongillo 2007), suggests that future expansion of the project should focus on women as the owners and operators of layer facilities in order to have the greatest impact on family health and welfare.

Limitations and future directions

There are a number of limitations to this study that should be noted. First, in the absence of a measured stressor or shock, we are limited in our ability to measure the resilience resulting from our programs. Instead, we must rely on static outcome measures as indicators of *potential* resilience. For example, while we argue that increased average flock sizes over time are an indicator of a more resilient village poultry system, we lack an objective measure of a stressor or shock (e.g. local Newcastle disease outbreak among unvaccinated flocks) to allow us to quantify it. Similarly, we suggest that increased HH income among egg producers contributes to HH resilience based on qualitative data from in-depth interviews with producers; again, however, without measures of actual shocks and HH responses, this cannot be quantified. Second, financial and technical limitations affected our ability to collect suitable control data in some cases, forcing us to rely on less appropriate counterfactuals. For instance, to assess the impact of the intervention of the profitability of village poultry, we relied on secondary analysis of a dataset that contained both COMACO and non-COMACO members, which may have made the difference in profitability appear artificially smaller than it actually was.

Finally, our exploration of the impact of local egg production on social resilience of the surrounding community is based on a small sample size of just 120 HHs in six communities (three project and three control areas). Additional research with a larger sample size is needed to further explore the link between local egg production and HH resilience mediated by nutrition. For example, despite their increased physical availability, will eggs be economically accessible for the poorest HHs in these communities on a routine basis? If a nutritional education program convinces parents to increase their HH food expenditures on eggs, will it come at the expense of grain and vegetable expenditures, leading to a net reduction in calories and certain micronutrients? Importantly, will the number of eggs that families are able to or be interested in consuming be sufficient to have a significant impact on nutritional outcomes? These questions need to be explored to identify the exact mechanisms by which local egg production affects the resilience of the Luangwa Valley system.

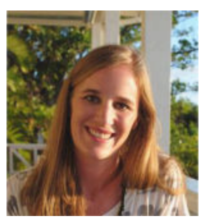
Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

We thank Drs. Kim Bothi, Gordon Hickey, Bernard Pelletier, and Andrew Mude for their critical evaluation of the manuscript. We thank the dedicated farmers, volunteers and staff working with COMACO for supporting and participating in this research, particularly Joel Ngumayo, Petronella Simwinga, Peter Banda, and Ruth Nabuyanda. Funding for COMACO has been provided by the Royal Norwegian Embassy, Howard Buffett Foundation, Mulago Foundation, Lundin Foundation, CARE International, General Mills, Royal Society for the Prevention of Cruelty to Animals International, William Lloyd, and Harvey and Heidi Bookman. Research funding was provided by the US Agency for International Development through the Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM-CRSP, EPP-A-00-04-00013-00, A.J.T. and D.L.), the National Institutes of Health Graduate Training Program in Comparative Medicine (T32OD011000, PI: John Parker, supporting S.E.D.), Cornell University's Expanding Horizons program (S.E.D., E.M., E.S., T.L., and K.B.), and Cornell University's Atkinson Center for a Sustainable Future (S.E.D. and A.J.T.). Technical support and guidance for the community vaccination program was initially provided by Drs. Robyn Alders and Brigitte Bagnol of the Kyeema Foundation's International Rural Poultry Centre (financially supported by the Wildlife Conservation Society and the SANREM-CRSP). Special thanks to Dr. Hayley Adams and the Silent Heroes Foundation for continued support of the Newcastle Disease community vaccination program. We note with sadness the passing of Dr. Benjamin Lucio-Martinez, who helped develop the poultry interventions and was not only a source of practical and technical knowledge, but also enthusiasm and caring for both people and poultry.

Biography



Sarah E. Dumas is a PhD student studying international nutrition and epidemiology at Cornell University. Dr. Dumas received her Doctor of Veterinary Medicine from Cornell University in 2012 and afterwards completed a clinical internship at the University of Illinois Rural Animal Health Management department. Her current research is positioned at the intersection of human, animal, and ecosystem health, with a specific focus on understanding how people in rural, resource-poor communities can sustainably produce their own animal source foods in order to increase their consumption among children at high risk of chronic undernutrition.

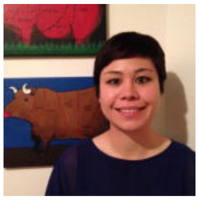
Luke Lungu is the Senior Poultry Manager at Community Markets for Conservation (COMACO) in Lundazi, Zambia, a position he has held for five years, where he oversees all poultry related programs benefiting over 15,000 vulnerable farmers in three districts in the Luangwa Valley.

Nathan Mulambaya is the Extension Regional Coordinator at Community Markets for Conservation (COMACO) in Mfuwe, Zambia, where he has worked since 2005. Mr. Mulambya holds multiple certificates in sustainable agriculture, adult education, and behavior change. In his current position, he oversees the implementation and evaluation of multiple conservation farming, agro-forestry, carbon (REDD+ and SALM), and health and family planning programs benefiting over 13,000 farming families in the Luangwa Valley.

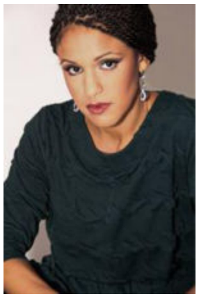
(No Photo)

Whiteson Daka is a Project Manager at Community Markets for Conservation (COMACO) in Chipata, Zambia, where he has worked since 2004. In Mr. Daka's current position, he supervises the Regional Extension Coordinators and Area Managers, overseeing projects benefiting over 43,000 households in the Luangwa Valley.

Erin McDonald graduated from Cornell University College of Veterinary Medicine in 2008. She currently works as a private practitioner of small animal medicine at Blairstown Animal Hospital in New Jersey.



Emily Stuebing is a Veterinary Corps Officer in the US Army Veterinary Corps. She received her Doctor of Veterinary Medicine at Cornell University College of Veterinary Medicine in 2010.



Tamika Lewis graduated from Cornell University College of Veterinary Medicine in 2009 and received her M.Ed. from Hunter College School of Education in 2005. She currently practices small animal general and emergency medicine at Westside Veterinary Center in New York City.

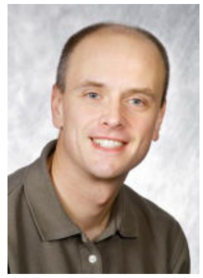
Katherine Backel graduated from Cornell University College of Veterinary Medicine in 2015 and is currently completing a small animal internship at Red Bank Veterinary Hospital in New Jersey.

Jarra Jagne is a veterinarian with over 21 years of experience in poultry disease management and control, public health and laboratory diagnostics. Dr. Jagne is a Senior

Extension Associate with Cornell's Animal Health Diagnostic Lab at the Cornell College of Veterinary Medicine. She has also worked for Development Alternatives Inc. (DAI), a consulting firm based in Bethesda, Maryland. She was the Senior Veterinary Advisor for STOP Avian Influenza (AI), a project administered by DAI and funded by the United States Agency for International Development (USAID). Before joining the STOP AI project, she worked for a year as a Veterinary Diagnostician with the Food and Agriculture Organization (FAO) of the United Nations in Rome, Italy. Dr. Jagne worked for seven years in the commercial poultry sector in the United States as a Technical Services Manager for ISA Babcock, a large poultry genetics company. Dr. Jagne holds a Doctor of Veterinary Medicine from Cornell University and a BSc in Biology from Colorado State University. She completed a two-year residency in Avian Diseases and Pathology at the University of Pennsylvania and is a Diplomate of the American College of Poultry Veterinarians.

Benjamin Lucio-Martinez completed his veterinary studies in 1964 at the Escuela Nacional de Medicina Veterinaria y Zootecnia (ENMVZ), Universidad Nacional Autónoma de México. He obtained his MS and PhD degrees from the College of Veterinary Medicine at Cornell University in 1968 and 1979. Together with several colleagues, he founded the Asociación Nacional de Especialistas en Ciencias Avícolas (ANECA) and was its founding president (1970-1972). In 1986 he joined the Department of Avian and Aquatic Animal Medicine at Cornell University. He retired in 2011 as Director of Avian Diagnostic and Extension Services at Cornell University. Dr. Lucio passed away in 2013. Throughout his career he worked on different projects, specializing in the diagnosis, control, and pathogenesis of poultry diseases. He worked on infectious bronchitis, avian encephalomyelitis, Newcastle disease, egg drop syndrome '76, infectious bursal disease, chicken infectious anemia, Marek's disease, and Salmonella Enteritidis in chickens. He also worked on canary pox, parrot pox and tragopan herpesvirus. He published more than 30 papers in peer-reviewed journals and was generous with his time and knowledge, training numerous veterinary students to improve poultry production in developing nations.

Dale Lewis is President, Founder of COMACO Ltd. and serves as its Director of Conservation and Agriculture and was its Chief Executive Officer from 2009-2013. He also holds the position as Senior Conservationist/ Scientist and Country Director for Wildlife Conservation Society in Zambia. Dr. Lewis has worked in Zambia for over 30 years developing various programs that have pioneered innovations for building synergies and workable landscape approaches for promoting conservation and improved rural livelihoods. Through this work he created a brand of food products called *It's WIld!,* which gets its raw materials from small-scale farmers who adopt conservation-based land use and farming practices. Dr. Lewis received his PhD from the University of Texas. He has published over 20 papers and one book.



Alexander Travis is a veterinarian and research scientist with 10 years of experience working on the twin challenges of fighting poverty and hunger using market-oriented approaches that promote sustainable intensification and environmental objectives. He was PI of a multi-disciplinary research grant (USAID SANREM-CRSP) that provided monitoring and evaluation of Community Markets for Conservation (COMACO), and performed research, technical consulting and extension training to optimize their efforts. He continues to work in Zambia on improvements in livestock husbandry/health, and design, implementation, and economic and human health evaluation of village-scale egg layer facilities. He has co-hosted an international workshop on biodiversity conservation and poverty traps, and co-edited a Special Feature in the Proceedings of the National Academy of Sciences USA, on "Biodiversity Conservation and Poverty Traps". He currently serves as the Faculty Director for the Environment for Cornell's Atkinson Center for a Sustainable Future, and as Associate Dean for International Programs in the College of Veterinary Medicine. He additionally co-founded the course *Conservation Medicine*, and co-organizes the course *Veterinarians in Developing Nations*. He also holds an NIH Pioneer Award for potentially transformative work in biomedical science.

Abbreviations

ASF	Animal source food
CF	Conservation farming
COMACO	Community Markets for Conservation HH Household
ND	Newcastle Disease

References

ADGER WN. Social and ecological resilience: are they related? Progress in Human Geography. 2000; 24:347–364.

ALBRECHT, RW. Luangwa Valley Conservation and Development Project: Land Use Development Proposals for the Mid and Upper Luangwa Watershed. Food and Agriculture Organization of the United Nations; Rome: 1973. Project FO:DP/ZAM/68/510, Working Document 3

ALLEN LH. Interventions for micronutrient deficiency control in developing countries: past, present and future. J Nutr. 2003; 133:3875S–3878S.

ALLEN LH. Global dietary patterns and diets in childhood: implications for health outcomes. Ann Nutr Metab. 2012; 61(Suppl 1):29–37. [PubMed: 23343945]

AREGHEORE, EM. Country Pasture/Forage Resource Profiles. FAO; Zambia. Rome, Italy: 2009.

BAGNOL, B. Trip Report to COMACO. WCS and KYEEMA Foundation; 2007. Improvement of village poultry production by communities surrounding South Luangwa National Park, Zambia..

BARRETT CB, CONSTAS MA. Toward a Theory of Resilience for International Development Applications. Proc Nat Acad Sci U S A. 2014; 111(40):14625–30.

CENTRAL STATISTICAL OFFICE (CSO), MINISTRY OF HEALTH, TROPICAL DISEASES RESEARCH CENTRE, UNIVERSITY OF ZAMBIA, & MACRO INTERNATIONAL, INC.. 2007 Zambia Demographic and Health Survey. CSO and Macro International Inc.; Calverton, Maryland, USA: 2009.

COMACO. Project Description Document for 2014-2018: Building links to last: small farmers, markets, conservation, and partners. Community Markets for Conservation; Lusaka, Zambia: 2014.

DODDS, DG.; PATTON, DR. Wildlife and Land-Use Survey of the Luangwa Valley. Food and Agriculture Organization of the United Nations; Rome: 1968. p. Rep TA2591

FAO.. [April 24, 2014] FAOSTAT Database, Food Balance Sheet [Online]. Available. 2012. http://faostat.fao.org/site/368/default.aspx#ancor.

FAO.. [April 1, 2015] Food Security Indicators [Online].. Economic and Social Development Department. 2014. Available: http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.U1kgU15UPIY.

HARRISON JL, ALDERS RG. An assessment of chicken husbandry including Newcastle disease control in rural areas of Chibuto, Mozambique. Tropical Animal Health and Production. 2010; 42:729–736. [PubMed: 19902375]

HARUN M, ALDERS RG, SPROWLES L, BAGNOL B, CAMBAZA AB, MSAMI H, MGOMEZULU R. Southern Africa Newcastle Disease Control Project impact studies: baseline and participatory rural appraisal results. ACIAR PROCEEDINGS. 2009; 131:96–101.

IFAD.. [April 29, 2012] Rural poverty in Zambia [Online]. Available. 2012. http://www.ruralpovertyportal.org/country/home/tags/zambia

INTERNATIONAL RURAL POULTRY CENTRE & COMACO. Controlling Newcastle Disease in Village Chickens: A Manual for Extension Workers. Community Markets for Conservation; Lusaka, Zambia: 2007.

LEROY JL, FRONGILLO EA. Can interventions to promote animal production ameliorate undernutrition? J Nutr. 2007; 137:2311–6. [PubMed: 17885016]

LEWIS D, BELL SD, FAY J, BOTHI KL, GATERE L, KABILA M, MUKAMBA M, MATOKWANI E, MUSHIMBALUME M, MORARU CI, LEHMANN J, LASSOIE J, WOLFE D, LEE DR, BUCK L, TRAVIS AJ. Community Markets for Conservation (COMACO) links biodiversity conservation with sustainable improvements in livelihoods and food production. Proc Natl Acad Sci U S A. 2011; 108:13957–62. [PubMed: 21873184]

LEWIS, D.; TEMBO, N.; NYIRENDA, P. Baseline analysis of rural household incomes in Luangwa Valley. Wildlife Conservation Society; Lusaka, Zambia: 2001.

MASSET E, HADDAD L, CORNELIUS A, ISAZA-CASTRO J. Effectiveness of agricultural interventions that aim to improve nutritional status of children: systematic review. BMJ. 2012; 344:d8222. [PubMed: 22251864]

MGOMEZULU, RA.; ALDERS, RG.; CHIKUNGWA, PB.; YOUNG, MP.; LIPITAL, WG.; WANDAL, GW. [April 12, 2014] Trials with a thermotolerant I-2 Newcastle disease vaccine in confined Australorp chickens and scavenging village chickens in Malawi. 2009. Available: http://aciar.gov.au/files/node/11133/PR131%20part%202.pdf.

NEUMANN C, HARRIS DM, ROGERS LM. Contribution of animal source foods in improving diet quality and function in children in the developing world. Nutrition Research. 2002; 22:193–220.

NGUMAYO, JC. Baseline study on rural community household livelihoods, gender, and social change. Luangwa Valley Ecosystem Integrated Conservation and Livelihood Project, Eastern Province. Luangwa Valley Ecosystem Integrated Conservation and Livelihood Project; Luangwa Valley, Zambia: 2011. Unpublished report

RANDOLPH TF, SCHELLING E, GRACE D, NICHOLSON CF, LEROY JL, COLE DC, DEMMENT MW, OMORE A, ZINSSTAG J, RUEL M. Invited review: Role of livestock in human nutrition and health for poverty reduction in developing countries. J Anim Sci. 2007; 85:2788–800. [PubMed: 17911229]

SONGOLO, A.; KATONGO, JC. SADC Planning Workshop on Newcastle Disease Control in Village Chickens. ACIAR Canberra; Maputo, Mozambique: Mar 6-9. 2001 2000 Country Report: Zambia.; p. 43-45.Proceedings N0 103

SPEEDY AW. Global Production and Consumption of Animal Source Foods. The Journal of Nutrition. 2003; 133:4048S–4053S. [PubMed: 14672310]

THURLOW, J.; ZHU, T.; DAIO, X. The impact of climate variability and change on economic growth and poverty in Zambia. International Food Policy Research Institute (IFPRI); 2009.

UNDP.. Human Development Report 2011. United Nations; New York: 2011. Sustainability and Equity: A Better Future for All..

UNSCN.. Sixth Report on the World Nutrition Situation: Progress in Nutrition. United Nations; New York: 2010.

USAID.. [April 1, 2015] The Resilience Agenda: Measuring Resilience in USAID [Online]. 2013. Available: http://www.usaid.gov/sites/default/files/documents/1866/Technical%20Note_Measuring%20Resilience%20in%20USAID_June%202013.pdf

WHALEY SE, SIGMAN M, NEUMANN C, BWIBO N, GUTHRIE D, WEISS RE, ALBER S, MURPHY SP. The impact of dietary intervention on the cognitive development of Kenyan school children. Journal of Nutrition. 2003; 133:3965S–3971S. [PubMed: 14672297]

WORLD BANK. Zambia Overview [Online]. World Bank; 2014. Available: http://www.worldbank.org/en/country/zambia/overview [April 12, 2014]

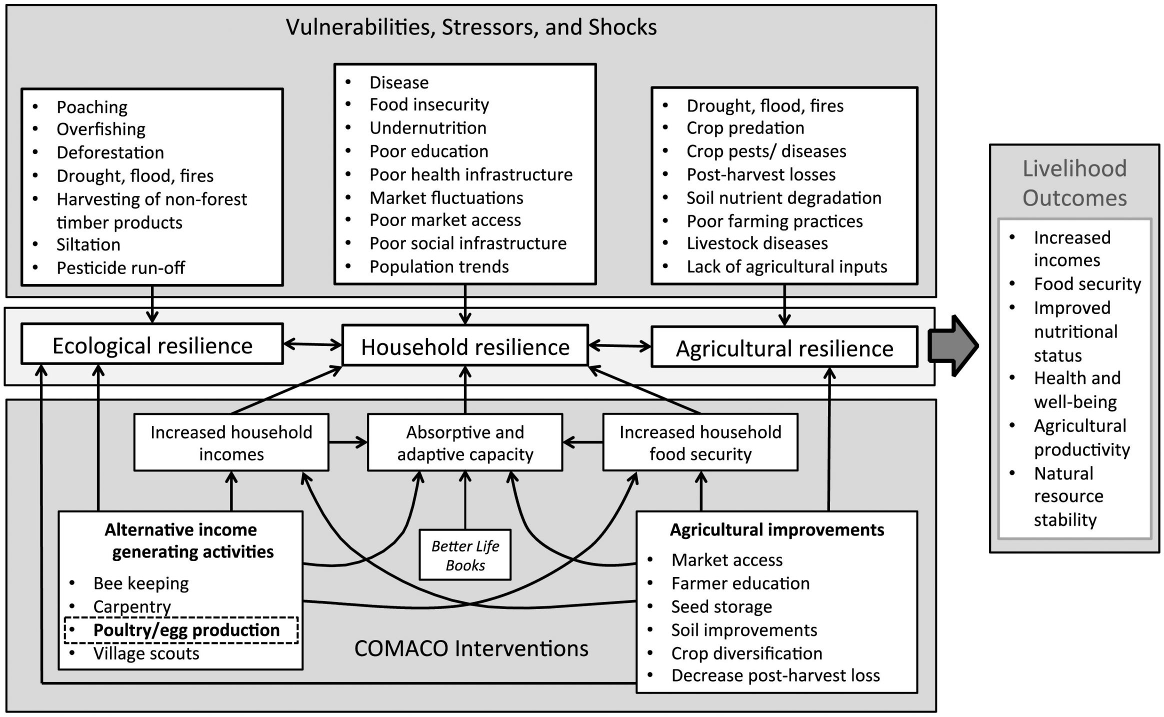


Figure 1.

A conceptual framework illustrating the theoretical mechanisms by which COMACO interventions promote household, agricultural, and ecological resilience and the measurable livelihood outcomes that result. Agricultural programs directly promote resilience of the agricultural system, as measured by annually increasing average yields per hectare and decreased rates of farm relocation. Agricultural programs indirectly contribute to household (HH) resilience by stabilizing the home generation of staple foods, increasing yields of cash crops and surplus food crops, and improving market access and produce prices. Alternative income-generating activities similarly promote HH resilience through increased HH incomes and, in the case of livestock interventions, the production of animal source foods for HH consumption, contributing to food security. Finally, all interventions contribute to ecological resilience through decreased reliance on the routine, seasonal, and urgent use of wildlife and natural resources as a livelihood strategy.

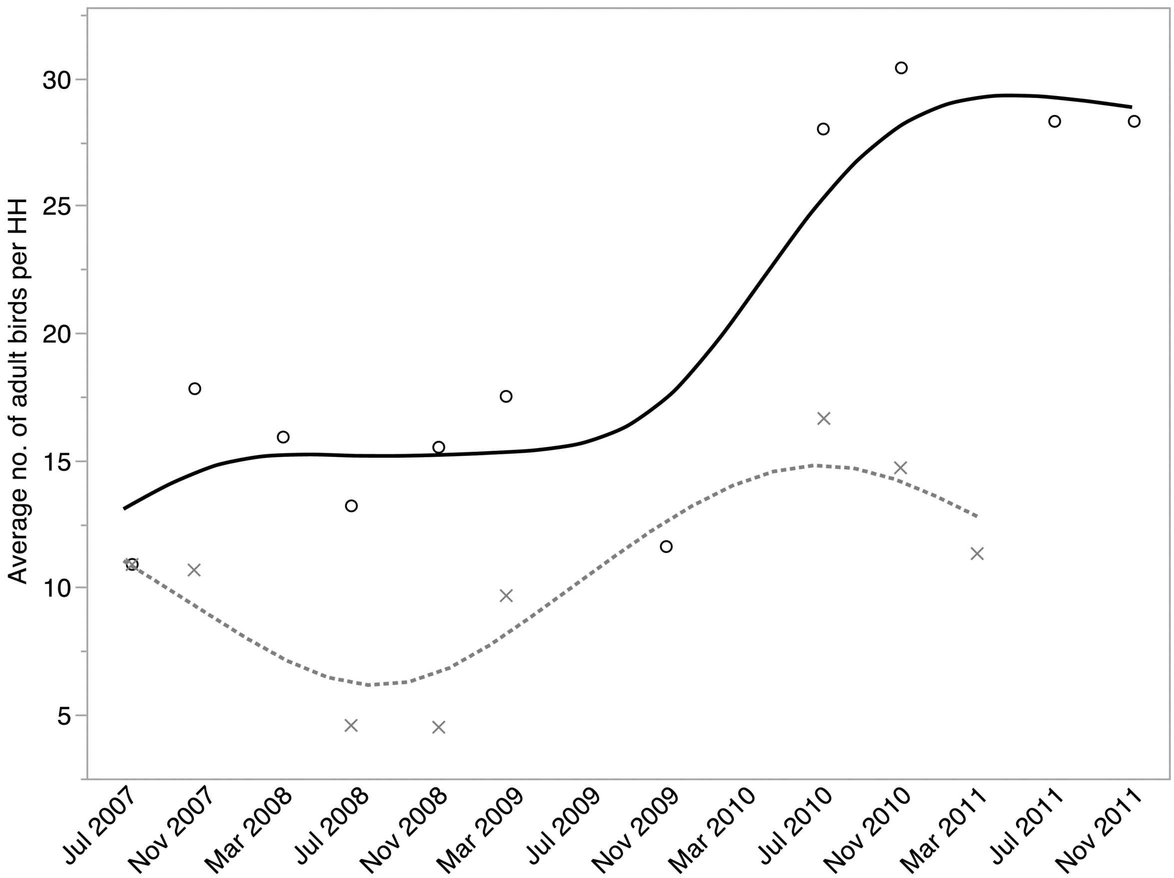


Figure 2.

Average household flock size increased 160% from July 2007 to November 2011 with regular Newcastle disease vaccination and improved management (vaccinating HH) versus controls (improved management alone). Vaccinations were not conducted in March 2010 or March 2011 due to heavy rains and impassable roads. Data for the July 2009 campaign were lost. Control data were not collected in March 2008, November 2009, July 2011, or November 2011 due to lack of funding. Abbreviations: HH= household.

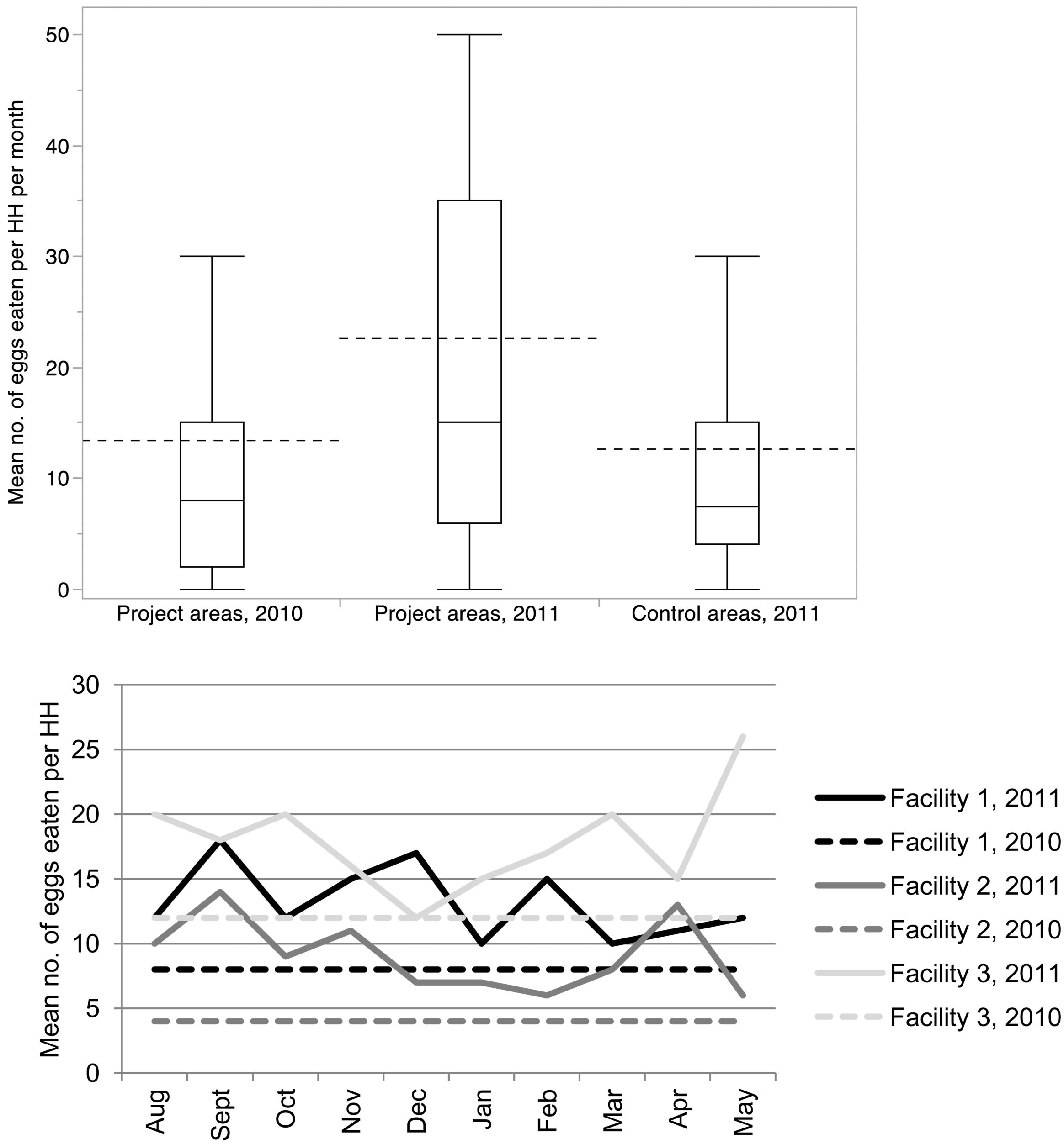


Figure 3.

Panel A: The self-reported number of eggs eaten per household per month over the past three months in communities surrounding pilot egg production facilities (project areas) and matched communities with no local egg production (control areas) after installation of the facility (2011) and before (2010, project areas only). The data are presented in an outlier boxplot, where the boundaries of the boxes represent the first and third quartiles (Q1 and Q3, respectively, such that the length of the box indicates the interquartile range [IQR]), the solid lines within the boxes display the median, and whiskers extend to the lowest and highest datum within 1.5 × IQR of Q1 and Q3, respectively. The mean is depicted by the broken line extending through each box. Outliers are not displayed. *Panel B:* Monthly egg consumption patterns in producer households for the 11 months after installation of the layer

facilities (2011) and the year prior to installation of the layer facilities (2010, estimated).
Abbreviations: HH= household

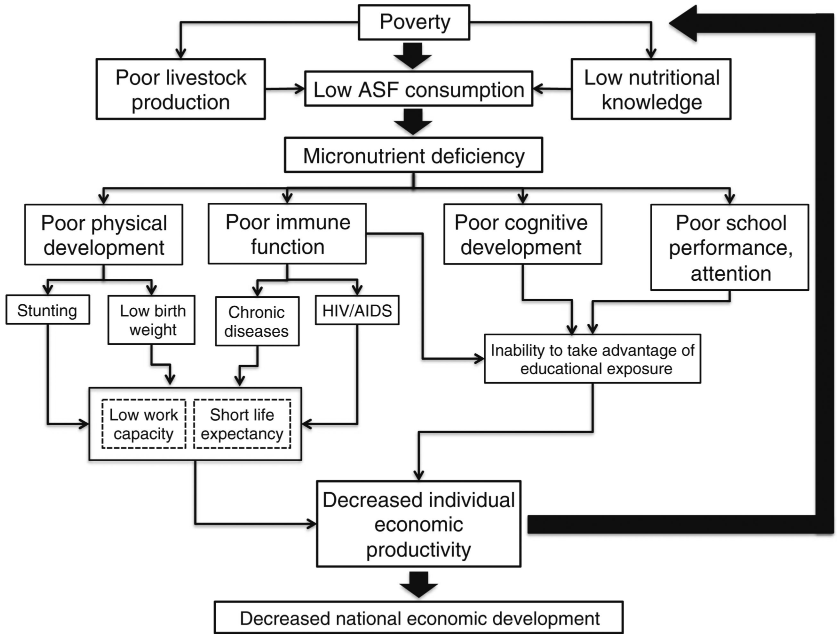


Figure 4.

Mechanisms by which poverty and low ASF consumption lead to reductions in human health and economic development, having negative impacts on HH and regional resilience.

Table 1

Adoption of recommended strategies in extensive village poultry production and the impact of the program on indicators of productivity.

	Baseline*	2011
Adoption of techniques		
Poultry groups		
Number of groups	0	395
Number of farmers	0	5,271
NDV vaccination		
Number of HH	280⁺	420
Number of chickens	2,900⁺	9,755
Night-time poultry housing, any (%)	0	91.5
Grounded (%)	NM, <5%	20.3
Elevated (%)	NM, <5%	71.2
Family home (%)	NM	8.5
Providing water and maize bran (%)	0	94.7
Maggots/termites (%)	0	3.5
Impact on productivity		
Avg. flock size (no. adult birds/HH)		
Vaccinating HH	10.7⁺	30.4
Non-vaccinating HH	10.7⁺	11.6
Income from poultry (US$/year)	16.89⁺⁺	40.25
HH chicken consumption (no. meals/month)	NM	1.7

Abbreviations: HH= household; NM= not measured

*Baseline estimates from 2006, unless otherwise indicated

⁺July 2007, at time of the first vaccination campaign

⁺⁺2001 estimate, adjusted for inflation to 2011 value (Lewis et al. 2001)

Table 2

Mechanisms by which COMACO's interventions are designed to promote social, agricultural and ecological resilience.

Social resilience
Increased HH food supply (FS-D)
Diversified diets including both vegetable and ASF sources (FS-D)
Increased market access (FS-I)
Increased incomes from crops (FS-I)
Diversified income sources (FS-I)
Knowledge sharing and development of new skills (producer groups and Better Life Books, FS-I)
Agricultural resilience
Improved soil quality (FS-D, FS-I)
Increased yields (FS-D, FS-I)
Drought resistance (FS-D, FS-I)
Crop diversification (FS-D, FS-I)
Ability to reestablish plots after crop loss (FS-D, FS-I)
Improved genetic diversity of crops (FS-D, FS-I)
Access to agricultural inputs (FS-D, FS-I)
Decreased poultry losses to disease and predation (FS-D, FS-I)
Improved egg production (FS-D, FS-I)
Ecological resilience
Decreased deforestation (decreased land clearance & charcoal production)
ASF production to replace bushmeat and fishing
Decreased pesticide and herbicide use
Decreased carbon emissions from residue burning
Increased carbon sequestration in soil

Abbreviations: FS-D= food-security, direct; FS-I= food-security, indirect