FINAL TECHNICAL REPORT / RAPPORT TECHNIQUE FINAL

SCALE UP OF HOMESTEAD FOOD PRODUCTION FOR IMPROVED HOUSEHOLD FOOD SECURITY AND NUTRITION IN CAMBODIA - FISH ON FARMS PHASE 2: FAMILY FARMS FOR THE FUTURE

Green, Tim;Michaux, Kristina;Moumin, Najma;Talukder, Zaman;

Helen Keller Internation Cambodia team;

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"Scale up of Homestead Food Production for improved household food security and nutrition in Cambodia"

FISH ON FARMS PHASE 2:

FAMILY FARMS FOR THE FUTURE

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Authors:

Tim Green, UBC/SAHMRI

Zaman Talukder, HKI

Kristina Michaux, UBC

Najma Moumin, UBC

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24-HDR	24 Hour Dietary Recall
BCC	Behaviour Change Communication
CARD	Council for Agriculture and Rural Development
CBA	Cost Benefit Analysis
CEA	Cost Effectiveness Analysis
CIFSRF	Canadian International Food Security Research Fund
CIHR	Canadian Institutes of Health Research
cRCT	Cluster Randomized Controlled Trial
DALYs	Disability-life adjusted years
EHFP	Enhanced Homestead Food Production
EIA	Environmental Impact Assessment
ENA	Essential Nutrition Actions
EAR	Estimated Average Requirement
FANTA	Food and Nutrition Technical Assistance
FoF	Fish on Farms
FF4F	Family Farms for the Future
FiA	Fisheries Administration
FCT	Food Composition Table
H.E.	His Excellency
HFP	Homestead Food Production
HH	Household
HKI	Helen Keller International
HQ	Headquarters
IDRC	International Development and Research Centre

IFPRI	International Food Policy and Research Institute
MAFF	Ministry of Agriculture, Fisheries, and Forestry
MoF	Ministry of Finance
MEYS	Ministry of Education, Youth and Sport
MoH	Ministry of Health
MoI	Ministry of Interior
MoP	Ministry of Planning
MPS	Minimum program standards
MRD	Ministry of Rural Development
NGO	Non-governmental Organization
NMB	Net monetary benefit
ODOV	Organization to Develop Our Villages
PDcRCT	Pragmatic Delayed Cluster Randomized Controlled Trial
PVT	Prom Vihear Thor
SAHMRI	South Australian Health and Medical Research Institute
SIS	Small Indigenous Species
ToT	Training of Trainers
UBC	The University of British Columbia
UN	United Nations
VHV	Village Health Volunteer
VMF	Village Model Farm
VP	Vice President
VSG	Village Support Group
WASH	Water, Sanitation, and Hygiene
WEAI	Women's Empowerment in Agriculture Index

1. EXECUTIVE SUMMARY

This final report is the culmination of two CIFSRF projects carried out in Cambodia, colloquially known as 'Fish on Farms' (FoF) and 'Family Farms for the Future' (FF4F) that together spanned over six years. The overall aim of both projects was to "to improve household food security and nutrition outcomes, livelihoods, and women's empowerment through an enhanced homestead food production (EHFP) model using an environmentally sustainable approach". In part one, FoF, we conducted a cluster randomised control trial (cRCT) of an integrated model of EHFP in which 900 women headed households in Prey Veng province were randomized to either plant-based EHFP, EHFP plus fishponds, or control. The participants received many benefits such as reduced food insecurity, increased fruit and vegetable production, increased fish production in households with fishponds, and increased income that was controlled by women and used to purchase animal-source foods or for children's education. However, a number of limitations were noted: women were not given a choice in the type of EHFP they received and may have been less motivated resulting in high attrition; almost all the costs of the intervention were borne by the project which in addition to not being sustainable may have led to less engagement by women farmers; insufficient time for EHFP to reach its full potential; issues with capturing the seasonality of crop production and nutrient intake; and lack of information on how EHFP might work in other areas in Cambodia, such as costal, highlands, and peri-urban areas.

The second phase of the project, FF4F, was designed to overcome some of these shortcomings. Here we aimed to develop a scalable, cost-effective model of EHFP for Cambodia. We incorporated successful components and lessons learned from FoF, refined tools, methodologies, and practices for scale-up in diverse agro-ecological zones and provinces (Kampot, Kampong Cham, Prey Veng, and peri-urban Phnom Penh) that included 4600 households. These households were able to choose the form of EHFP they wanted, which included a mix of gardens, poultry, and fishponds, but were expected to contribute more to the establishment of these homestead farms. In addition to the scale up, we conducted a pragmatic-delayed cluster randomized control trial (PDcRCT) nested within the larger FF4F study in Kampot province. In short, villages were randomized to EHFP of the households choosing, or control. During the first year, EHFP was introduced into the intervention villages (any type of EHFP) but no measurements were made. In the control group production was quantified monthly and detailed 24-hour dietary recalls were conducted with recipients (women and children) during lean (May) and peak (Dec) production periods in year one. In year two, we quantified production and dietary intake in the groups receiving EHFP.

With the stage set for the background we now focus on the key outputs and learnings from the last three years. Initially, households were expected to contribute 50% of the costs of the inputs required to set up their EHFP farms, but with extensive feedback from beneficiaries, this was reduced to 30% to ensure greater uptake of the program. Some households relied on microcredit but most relied on personal family funds. We targeted 4600 households, but through spill-over we estimate that the project reached another 15 households per study village. Members of these households either attended training, education, and/or demonstration events. In total, we estimate that 3,500 non-target households received benefits from this project, thus benefiting an estimated 17,500 family members overall. Attrition was high in non-surveillance households at over 40%. The main reasons given for attrition were migration for other economic opportunities and lack of time and labour resources. Fortunately, attrition occurred early and households could be replaced before considerable resources were spent. All provinces except the city of

Phnom Penh took up aquaculture ranging from 23% in Kampong Cham to 54% in Kampot. Poultry raising took place in excess of 90% of houses in all provinces. In addition to initially poor-quality seeds, poultry death was high and plans were taken to mitigate this high mortality. Another strength of the study was that we followed up with both inactive and active households to explore the main factors contributing to retention and adoption of practices promoted by the project.

Based on data from our PDcRCT trial, we found significant differences in agriculture production and prevalence of inadequacy for key micronutrients between households that received the EHFP intervention (regardless of model) versus the control group. Specifically, of producing households in each category, on average, households in the EHFP group produced significantly more fruit (507 vs. 306 kg), large fish (23 vs. 15 kg), eggs (117 vs. 99 units), and live birds (99 vs. 89 units) than the control group, however, cumulative vegetable production, while different (267 vs 192 kg) was not statistically significant. For food intake, we observed a statistically significant reduction in the prevalence of inadequate intake for zinc, thiamin, riboflavin, and vitamin A in women and children in the EHFP group compared to control, during both the lean and peak agricultural seasons. Over the two-year intervention, the project was cost neutral, when accounting for only targeted households. However, if projected out over a ten-year period the incremental net benefit was nearly USD500. Further, if you take into consideration the spill-over effect, the project is likely to have even larger positive net benefit.

All project objectives were met. Briefly, we refined technologies and practices from FoF and adapted them for different geographic regions and scale. Different types of fish and stocking densities were tested and small-scale hatcheries were encouraged such that now we feel that Cambodia has a sustainable model for fish hatcheries moving forward, which can be managed by the Fisheries Administration (FiA). We increased agricultural productivity such that the number of households with cultivated gardens rose from 60 to nearly 100%. To date, FF4F farms have contributed an estimated 28,000 kg of fish, 260,000 poultry eggs and 6,000,000 kg of fruit and vegetables to the local food supply. Women's empowerment increased although we were not able to measure all dimensions. By the end of the study women were making 90% of the decisions around farming, specially, women's autonomy over food-crop and cash-crop farming increased (72% to 82% and 71% to 83, respectively); a recommendation was made to CARD that gender be incorporated into their trainings and future policies. We improved access to resources, and/or markets and income. A series of business tools and initiatives have also been piloted and shown to improve crop selection decision-making, beneficiary financial planning, and market access. Using zinc as the model nutrient we were able to show the incidence and mortality rates of zinc deficiency could be reduced by 23.4%

We had in mind that our ultimate our goal is to transfer the skills and learnings to the government, private industry, and civil society to benefit as many Cambodians as possible. As major outputs, a dissemination workshop was carried out where Cambodian representatives reaffirmed their support for EHFP. A policy brief has been prepared and a number of manuscripts have been published or are under consideration. HKI is sharing their learnings with neighbouring countries through regional workshops and are implementing parts of the innovative surveillance to better track production of EHFP outputs and costs incurred (inputs) in about 600 households in northern Vietnam and 10,000 households in Myanmar. HKI is a key informant to Cambodia's National Strategy for Food Security and Nutrition which will be developed for the next five-year period covering 2019-2023.

In summary, this project has had great successes, a few failures, but with important lessons learned. Agricultural interventions such as EHFP will struggle to show improvement in nutrition indicators, due in part to the short duration of most research projects. Improvements in stunting are inter-generational and include not only greater access to better food but improvements in socio-economic status as a whole. A lot of our modelling is based on a ten-year projection. The reality is we don't know what happens to these farms when donors pull out. We hope government and other organizations step up to fill the gap, but we simply don't know the long-term impact of EHFP. It would seem essential to return to these households in five years to see the longer-term impact.

Finally, we would like to highlight some of the spin-off successes that stem directly from this project. Through this study we were able to bring the leading expert from Harvest Plus to train Cambodian and international nutrition researchers on how to conduct proper 24-dietary hour recalls in resource-poor settings. We held focus groups to establish common recipes and created a Cambodian Food Composition Database, that is now in the public domain. This will be essential for future researcher planners, including those wanting to do National Nutrition Surveys. The initial aim of FoF was to reduce iron deficiency anemia in Cambodian women. Through careful study we determined that anemia in Cambodia was largely caused by genetic blood disorders. Working with HKI and funds from the Canadian Institute of Health Research, we proved that iron was not the cause of anemia and iron might be doing harm. In response the Cambodian government ceased weekly iron and folic acid supplements for non-pregnant women. We also noted that there were high cases of infantile beriberi (thiamine deficiency) in Cambodia. With funding from Grand Challenges Canada and with generous in-kind support from HKI we were able to fortify fish sauce with thiamine and give it to pregnant women to improve both theirs's and their infant's thiamine levels in blood. This is now being applied to salt and the team has been given over a million USD in additional funding from the Bill and Melinda Gates Foundation through The Sackler Institute for Nutrition Science. Directly and indirectly through this project we have helped trained the next generation of Canadian nutrition researchers with skills to work in low income countries; this includes two PhDs, three MSc, three research assistants, and countless undergraduate nutrition, business, and public health students.

2. THE RESEARCH PROBLEM

Despite Cambodia's economic success in recent years, approximately 18% of households are living below the poverty line (<1.90USD/day), with a greater number of rural households impacted (21%). Most rural Cambodian households engage in subsistence agriculture; however, poor land utilization, dependence on rain-fed agriculture and lack of agro-processing infrastructures result in seasonal food shortages and persistence food insecurity. To combat these issues, Helen Keller International (HKI) has implemented an EHFP model in Cambodia. HKI's EHFP program promotes year-round environmentally sustainable food production by providing vulnerable women farmers and their families with initial inputs and technical training on improved agriculture practices in concert with nutrition, hygiene, gender and financial training. However, the efficacy of EHFP in improving food security and nutritional status in Cambodia has yet to be fully evaluated. Accordingly, the University of British Columbia (UBC) in collaboration with HKI, through CIFSRF Phase 1 funding, conducted a cRCT called FoF, to assess the impact of two different models of EHFP (gardens only and gardens + small-scale polyculture) at improving food security, nutrition, and women's empowerment in Cambodia. In total, 900 households were randomly assigned to one of three treatment arms: 1) EHFP (gardens only); 2) EHFP+F (gardens + fishponds); or 3) control. Both EHFP and EHFP+F households received inputs for household fruit and vegetable production; however, only the EHFP+F group received inputs for small-scale pond aquaculture. After completion of the 22-month trial, several outcomes were measured, including food production, income, food security, dietary diversity, biochemical and dietary intake. For the intervention groups, improvements were marked on a number of outcomes compared to controls; however, the project was not without its fair share of challenges. Attrition rates due to wage labour migration were high, a likely consequence of high donor investment and low beneficiary buy-in of EHFP. Moreover, the lack of diverse market linkages for sale of surplus produce; persistent gendered divisions of labour; and seasonality of food production and aquaculture were highlighted as barriers to continued uptake of EHFP among beneficiaries. In addition to the gaps identified in FoF, questions regarding the scalability of the project both horizontally, across geographically diverse regions, and vertically, through the development of national and international food security and nutrition policies, arose. Thus, through renewed funding from CIFSRF Phase 2, FF4F was created to address the gaps identified by the FoF trial and enhance existing knowledge, policies, and programs.

To minimize attrition and encourage stronger buy-in from beneficiaries of the FF4F project, participants were allowed to self-select EHFP models based on needs and preferences. Households were also required to contribute financially, with cash or in-kind support, to acquire inputs for homestead food production (HFP). A number of major changes were also made to the project training and behaviour change communication (BCC) materials from FoF including revisions to the women's empowerment training and tools to address the persistent gender inequities in Cambodia and marketing and entrepreneurship training that prioritized the needs and barriers to increasing households' income and savings from HFP. Additionally, the FF4F project targeted households in four provinces so the study sample better reflected Cambodia's social, economic, geographic, and cultural diversity. In addition to improved program delivery, FF4F also embedded a PDcRCT, called the '*Surveillance trial'*, to more rigorously evaluate agricultural production and dietary patterns in a subset of the study population. Ultimately, this research will be used to further refine and scale up EHFP in Cambodia and elsewhere.

3. PROGRESS TOWARDS MILESTONES

All of the milestones established for the roughly 3-year project period have been achieved. The nine milestones addressed below in the reporting period are as follows:

3.1 Fourth Nutrition Bulletin

In lieu of a business case analysis on the impact of microcredit on HFP, we have opted to develop a fourth Nutrition Bulletin (**Annex 1**) that captures the multitude of ways in which households have financed their homestead farms and/or provide the required 30% cost-sharing contribution, a cornerstone of the FF4F project. In addition to assessing changes in uptake and utilization of microcredit throughout the project, we also sought to determine the contribution of microcredit towards HFP relative to other financial resources among households that remained active in the project and the impact this had on agricultural productivity. Data collected during the baseline and end-line surveys show that at over the course of the project, the amount of microcredit loans taken by participants decreased, but the average value of the loans that were taken nearly doubled. However, while a substantial proportion (~25%) of participants took microcredit loans to pay for agricultural inputs and participate in the EHFP program, almost all participants acknowledged that the majority of these costs were paid from using their own personal savings rather than microcredit loans. These findings suggest that households do not require microcredit loans to participate in an agriculture project, such as FF4F, but do have potential for financial gain from EHFP if they are inclined to use their personal saving.

3.2 Economic evaluation

The last round of production/market surveys was completed in Jan/Feb 2018. Using these data, a cost-benefit analysis (CBA) was conducted to assess the incremental net monetary benefit (INMB) of the FF4F program relative to no program, from a societal perspective (the base case). The costs of program delivery included initial investments (e.g. capital costs, formative research), start-up costs (e.g. pond digging or renovation, poultry house construction, and initial capacity building/training), ongoing costs (e.g. refresher training, annual HFP input procurement), and opportunity costs (e.g. cost of time away from normal duties and time spent attending meetings/training). Benefits were quantified as the monetized value of increased agricultural production (including vegetables, fruit, fish and poultry). In brief, over the two-year implementation period, the program appears to be cost-neutral (-$2.90USD per household) with the incremental costs calculated as $288.71 per household and an incremental benefit of $285.81 per household. However, if a 10-year time horizon is used, the program appears to have a net positive benefit of $477USD per household (**Table 1**). A draft publication of the CBA results titled, '*Economic Evaluation of an Enhanced Homestead Food Production Intervention for Undernutrition in Women and Children in Rural Cambodia'***,** was presented at the Vancouver Health Economics Methodology (VanHEM) Group in May 2018 (**Annex 2**). VanHEM is a local Vancouver meeting where selected participants are invited to present papers in progress for feedback from local experts prior to publication. The project team received invaluable feedback from economists and other international experts during this meeting and are currently revising the paper for submission to a high-impact economic or global health journal by the end of July 2018.

In addition to the CBA, a cost-effectiveness analysis (CEA) was conducted, which examined the economic impact of the FF4F program by mapping a change in zinc intake into the number of potential disability-life adjusted life years (DALYs) averted. The results of the CEA are quite positive and suggest that 32.7 DALYs could be averted per 1000 households with the implementation of the FF4F program, over a 10-year time horizon. This translates into a net monetary benefit (NMB) of $315,671USD. The results of the CEA are further detailed in ***section 4.4.2.***

3.3 End-line survey report

Rather than conducting a cross-sectional survey of households that remained *active* in the project at end-line, we employed a longitudinal design and interviewed the households that were part of the original baseline sample. This allowed us to trace the movement of households throughout the life cycle of the project, measure change in outcomes from baseline to end-line and explore reasons for attrition. At baseline (April 2016) n=1087 households were interviewed in the four project areas, Kampot, Kampong Cham, Prey Veng and the peri urban district of Phnom Penh, Khan Meanchey. At end-line (February 2018) these same households were revisited (n=751), with the exception of the *Surveillance trial* control households (n=336), with a drop-out rate of 41% (**Table 2)**. Drop-out was defined as households that did not receive seeds during the last seed distribution in Dec 2017/Feb 2018 and were unwilling or unable to participate in the FF4F project. Of the *active* households (n=441), only n=407 were available for an interview at end-line; n=34 were missing during the data collection period but were still classified as *activ*e as they received seeds during the last distribution round. The number of households interviewed in each province were as follows: Kampong Cham n=101; Kampot n=218; Phnom Penh =16; and Prey Veng n=72.

The same basic tools were used for both surveys, but additional questions were added to the end-line questionnaire, including: (i) detailed information on aquaculture and poultry production; (ii) number of varieties and type of vegetables/fruit produced (iii) frequency of contact with project staff; (iv) level of participation in project training; and (v) information on household cost-sharing contributions for EHFP (see **Annex 3a** for the end-line survey tool). The aim of the household surveys were to assess changes over time (from baseline to end-line) on the following key outcome measures: 1) HFP and agricultural practices (horticulture, poultry and aquaculture production); 2) women's empowerment in agricultural production and income generation; 3) water, sanitation and hygiene practices; 4) household food security; 5) knowledge and practices related to maternal and child health and nutrition; 6) access to credit and financial literacy; and 7) anthropometric measurements of women of reproductive age (WRA) and children under five years of age (see **Annex 3b** for the full protocol). In addition to the end-line survey, an attrition follow-up survey was conducting with households that dropped out since project implementation ('*inactive*' households). The purpose of the attrition survey was to better understand the main drivers of dropout and the extent to which HFP practices, if any, were sustained among *inactive* households. By following up with households who dropped out, we were also able to compare differences between *inactive* and *active* households and explore the main factors contributing to retention and adoption of practices promoted by the project. The main results of the end-line and attrition surveys are described in greater detail in ***section 4.1.3*** and the full report is attached in **Annex 3c.**

3.4 Impact of four HFP models tested at scale

Due to the design of our scale up study, self-selection of EHFP models based on interest and willingness to cost-share, the selection of EHFP models was not uniform among beneficiaries and therefore we cannot compare results across models; however, we do have data from the *Surveillance trial* that allow us to compare differences in dietary intake and production between intervention (any type of EHFP model) and control households. Based on data from our *Surveillance trial*, we found significant differences in agriculture production and prevalence of inadequacy for key micronutrients between households that received the EHFP intervention (regardless of model) versus the control group. Specifically, of producing households in each category, on average, households in the EHFP group produced significantly more fruit (507 kg vs. 306 kg), large fish (23 kg vs. 15 kg), eggs (117 units vs. 99 units), and live birds (99 units vs. 89 units) than the control group, however, cumulative vegetable production was similar between groups (267 kg vs 192 kg). Furthermore, when HFP production was compared between groups and across months, EHFP households produced significantly more vegetables in May (37.8 kg for EHFP vs. 19.4 kg for control; $p < 0.05$) and June (35.7 kg for EHFP vs. 13.8 kg for control; $p < 0.05$); more fruit in July through Dec ($p<0.05$); more small and large fish throughout the year (May - Dec; $p<0.05$), and live poultry birds in May through to July ($p<0.05$) (**Table 3).**

For food intake, we observed a statistically significant reduction in the prevalence of inadequate intake for zinc, thiamin, riboflavin, and vitamin A in women and children in the EHFP group compared to control, during both the lean (May) and peak (December) agricultural seasons. These findings suggest that the FF4F program helped farming households cope with the seasonality of agriculture production with greater HFP outputs (particularly vegetables) and food intake observed during the lean season but not during the rainy, harvest season, when food is more plentiful. More details of the *Surveillance trial* outcomes can be found in ***section 4.4.***

Additionally, based on end-line data, certain patterns emerged among households on geographical preference of EHFP model type. Among respondents engaged in aquaculture, 54% were from Kampot compared to 23% in Kampong Cham and 28% in Prey Veng. Interestingly, in the peri-urban area of Phnom Penh, no households self-selected aquaculture. Poultry raising on the other had was widely taken up across all project areas, and more than 90% of households engaged in gardens + poultry.

3.5 Dissemination workshop

On May 5th, 2018, HKI and UBC hosted a public Dissemination Workshop in Phnom Penh for the FF4F project in collaboration with our government partners, FiA and Ministry of Agriculture and Forestry and Fisheries (MAFF); and our local implementing partners, Prom Vihear Thor (PVT), Village Support Group (VSG) and Organization to Develop Our Villages (ODOV). The objectives of this workshop were to share key results from the FF4F project and to generate a discussion around different components (e.g. agriculture, aquaculture, poultry, gender, nutrition and BCC, etc.) as a means of improving nutrition and food security in rural Cambodia. A total of eighty-five people participated in the workshop, representing fifty-five organizations including local and international non-governmental organizations (NGOs), donor organizations, United Nation (UN) agencies, national, provincial and district level government departments, and universities. The participant list for this workshop can be found in **Annex 4a.**

In his opening remarks, His Excellency (H.E.), Sok Silo, Deputy General Secretary of the Council for Agricultural and Rural Development (CARD) – the national coordinating body for food security and nutrition and Country Coordinator for SUN Movement - highlighted the importance of integrated community-based interventions as a means to improve food security and nutrition in Cambodia. He went on to say that the FF4F project is a shining example of how integrated interventions could be achieved for improved food security and nutrition in rural areas. H.E. also remarked that CARD is looking forward to discussing the lessons learned and best practices from the project and how to best use the findings to inform the next national strategy on food security and nutrition in Cambodia. After the presentations on key results, a panel discussion session was held in the afternoon, which explored many interesting questions on the experiences of the FF4F project, specifically regarding research gaps, donor priorities, and potential policy implications. During the closing remarks by H.E Eng Cheasan, Director General, FiA, MAFF, H.E. stated that the FiA valued the success of this project, especially the innovation of the poly-culture of small and large fish and explained how FiA has incorporated this model of poly-culture in their various policy and strategy documents, including their fish production training and strategy. A more detailed summary of the workshop can be found in **Annex 4b.**

3.6 Protocols refined and revised for optimizing aquaculture

HKI, together with Cambodia's Fisheries Administration, have refined the aquaculture protocol based on a combination of lessons learned from fish polyculture during the FoF trial and experiences gained during implementation of FF4F and through the FF4F aquaculture research study. The main revisions made to the aquaculture protocols in FF4F were as follows: i) improvements in the hatchery system, including the introduction of a simple water aeration system and changes to construction materials used for water and hatching tanks at the breeding stage; ii) revisions to the recommended number of large fish species raised with small indigenous species (SIS) from three to five to increase income earned from aquaculture products; and iii) changes to the initial stocking density of large fish species to address barriers to productivity. See **Annex 5** for the updated aquaculture protocols.

3.7 Policy brief

Cambodia's National Strategy for Food Security and Nutrition will be developed for the next five-year period covering 2019-2023. In preparation for this process, HKI participated in the mid-term review of Cambodia's current national strategy (2014-2018), serving as a core member of the National Advisory Board consisting of the CARD, the UN Resident Coordinator, representatives of different line ministries, and USAID, a donor representative (see **Annex 6a** for a copy of the mid-term and strategic review presentation). As an active member of the board, HKI worked with different stakeholders to discuss and identify gaps and challenges in the current strategy and determine key areas for improvement. Additionally, HKI contributed technical input to the development of the mid-term review report by ensuring that improvements in food security and nutrition through sustainable agriculture was a cornerstone of the recommendations in the five-year strategy (see **Annex 6b** for a copy of the presentation highlighting the findings of the advisory board's mid-term review). Given HKI's strong and enduring relationship with the Cambodian government and their extensive nutrition expertise, they are well positioned to use results and learnings from the FF4F project to influence the next five-year National Strategy for Food Security and Nutrition. HKI and UBC have prepared a policy brief (**Annex 7**) summarizing lessons learned and best practices from both phases of the project and will share it with CARD and other stakeholders before the

development of next National Strategy which is scheduled to begin after the national election (July 29, 2018).

3.8 Evidence based articles

During the 3-year span of the FF4F project, UBC and HKI have submitted seven manuscripts for publication to a wide-array of high impact peer-reviewed journals, including the *Journal of Nutrition*, *Nutrients*, and *Maternal and Child Nutrition*. More specifically, four papers have been accepted for publication while two are currently under peer review in *Maternal and Child Nutrition (***Annex 8a***),* and *Global Health: Science and Practice* **(Annex 8b)**, and two draft papers are *in-progress* (drafts) and will be submitted for publication by the end of July/August 2018. One of the *in-progress* papers uses the 24-hour dietary recall (24 HDR) data to explore the impact of any type of EHFP model on dietary intake of women and children during different growing seasons (**Annex 8c**); and the second *in-progress* paper summarizes the potential economic impact of the FF4F program and is currently being revised for submission to a high-impact economic journal. In addition to peer-reviewed articles, four nutrition bulletins have been produced and disseminated throughout the lifecycle of this project and disseminated widely with key national and international stakeholders.

3.9 HKI regional HFP knowledge exchange workshop

HKI held an Asia-Pacific Regional meeting on their global EHFP program during January 15-18, 2018 at Khmer Surin hotel in Phnom Penh, Cambodia. In total, 25 HKI staff attended this meeting, including the Asia Pacific Program Director, Asia Pacific M&E Advisor, Asia Pacific Vice President (VP), Country Directors, technical experts from HKI Africa Regional Office, HKI technical focal points from countries in the Asia Pacific region, along with Senior VP for Nutrition and VP for Nutrition from HKI headquarters. The overall goal of the meeting was to standardize and adopt tools and methods in order to improve replicability and impact of EHFP and to assist operationalization of EHFP minimum program standards (MPS). The following six action points were agreed on in the meeting as next steps: i) promote systematic and required training (or at least an orientation) on project management at various levels, with priority given to the country level staff; ii) standardize user-friendly project management cycle tools and explanations on their use, and include these in the EHFP Toolkit; iii) discuss steps towards a more systematic onboarding procedure; iv) discuss an institutional project start-up and close-out manual for operations, logistics and management needs; v) create guidelines and tools on consortium and partner management; and vi) improve HKI's communication strategy, including communications support, website use and social media protocols, particularly for country offices and programs. A more detailed description of the meeting objectives and outcomes are detailed in a report in **Annex 9** and in ***section 4.3.1.***

4. SYNTHESIS OF RESEARCH RESULTS TO DATE

In the following section we have highlighted and synthesized key scale up and research findings in accordance with the project objectives.

4.1 Objective 1: Refine technologies, methodologies and practices for EHFP developed and tested in Fish on Farms and adapt them for different geographic regions, contexts and scale

During FoF, we introduced a novel, environmentally sustainable, EHFP model that integrated small-scale polyculture (fishponds) with homestead fruit and vegetable production (home gardens). Based on key learnings from the FoF trial, we refined this model further and tested it at scale along with two other EHFP models, gardens only and gardens + poultry, in diverse agro-ecological zones. The following four sections summarizes results from the aquaculture research study that informed revisions to aquaculture guidelines, the follow up environmental assessment conducted by the FF4F team, and the overall impact and reach of the FF4F program, based on results from the baseline/end-line and attrition surveys.

4.1.1 Aquaculture research results

In collaboration with FiA, the FF4F team conducted a quasi-experimental study to determine the most optimal proportion and combination of SIS and large species in small scale aquaculture (see **Annex 10** for the aquaculture research report). In total, 12 fish farmers were assigned to one of two treatment groups differing only in respect to the proportion of each of the five large fish species given. Farmers in the first treatment group were provided with 0.5kg of SIS in combination with the following proportions of large fish: 40% Silver Barb, 10% Mrigal, 10% Reho, 10% common carb, and 30% Tilapia. In the second arm, farmers were provided with 0.5kg of SIS to be raised in concert with the following proportion of large fish species: 30% Silver Barb, 25% of Mrigal, 25% of Reho, 10% of common carb, and 10% of Tilapia.

After 6 months of monitoring, higher growth rates and production of SIS were observed in the second treatment arm: group two harvested approximately 0.5 kg more SIS than group one. In addition, group 2 a 53% greater survival rate compared to group one for large fish species. Several factors could possibly explain this: the lower proportion of tilapia, an omnivore, co-existing with SIS may have reduced overall SIS mortality rates in group two; variation in frequency and quality of fish feed may have impacted growth; pond water quality may have differed based on individual farmer management practices and finally; presence of predators in fishponds and differences in farmers' mitigation strategies may have also resulted in differences in productivity.

Key findings from this study along with ideal pond management and fish raising techniques were incorporated into aquaculture best practices guidelines. Specifically, optimal stocking densities for small scale polyculture were revised according to the ratios of small and large fish species used in group two as this configuration demonstrated both higher survival rates and productivity of SIS. Additionally, revisions to hatchery system construction and operations, discussed in the fourth technical report, have contributed to improvements in fry production by approximately 30%. Building off of lessons learned from FoF and subsequently FF4F, aquaculture guidelines have been tested and refined so as to maximize not only small-scale production at the household level but also production at the community level by improving hatchery and nursery productivity. Improved guidelines will also serve as a valuable resource for FiA as the ministry incorporates key learnings into its promotion strategy for future small-scale aquaculture programs in Cambodia.

4.1.2 Follow up Environmental Assessment

A follow-up Environmental Assessment (EIA) was conducted at all eight fish hatcheries by HKI in August 2017. During the EIA, HKI monitored the implementation of mitigation measures taken to reduce, control or eliminate adverse environmental effects from the project. Three key issues/risks identified from the initial assessment that were of particular importance: (i) possibility of soil erosion; (ii) fuel leak/spill from water pumping equipment contaminating hatchery pond or groundwater through the soil; and (iii) risk of

contamination from latrine or accumulated livestock waste located less than 15 metres ponds. Thus far, there have been no documented cases of adverse environmental effects and the recommended mitigation actions were consistently applied in all eight hatcheries. It was documented that, where possible, hatchery owners planted up/on pond banks and bunds immediately post excavation, removed soil contaminated by burning of inorganic rubbish, constructed ponds at least 30 meters from fields where fertilizers and/or pesticides were used, and ensured latrines were sealed or located >30 meters from ponds to reduce risk of ground water contaminations. The full follow-up EIA report was reported in the 30-month technical report.

4.1.3 End-line survey research results

As part of the overall evaluation of the FF4F program, we conducted two household surveys with a random sample of the full study population. In the following section we describe the main objectives, methods and results of the household surveys and implications of the findings.

4.1.3.1 End-line Survey Objectives

A longitudinal research design was employed in the end-line survey. Households interviewed at baseline were revisited to assess changes over time on the following outcome variables: i) horticulture practices and production; ii) women's empowerment; iii) WASH; iv) infant and young child feeding practices and women's health seeking behaviours; v) household food security status; and vi) anthropometric measurements of WRA and children 6-59 months at enrollment. Additionally, we collected information on the following items that were not examined at baseline: i) the extent to which EHFP promoted technologies and practices were maintained among those who remained in the project; ii) aquaculture and poultry production; iii) EHFP training modules received; and iv) contact time with project staff.

By following up with the same respondents interviewed at baseline, we were able to better understand patterns of attrition among those that have chosen to leave the project. Employing a condensed version of the end-line survey, the attrition survey specifically focused on extracting the following information: i) the main drivers of attrition and time point at which dropout occurred; ii) extent to which EHFP technologies, methodologies and practices were adopted among inactive households; iii) horticulture, aquaculture and poultry production over the past two months; iv) EHFP training modules received; and v) contact time with project staff (see **Annex 11** for the full attrition survey tool).

4.1.3.2 End-line survey sampling procedure

At baseline (April 2016), n=1087 households were interviewed. All except the *Surveillance trial* control households (n=336) were visited for follow up at end-line (February 2018). The surveillance control group was excluded as they had only had one year of project implementation and would therefore be an inappropriate comparison. Thus, n=751 households were visited, 407 of whom remained active and were available for interview, and 37 of whom were active but unavailable for interview during the data collection period. Among those households classified as dropout (n=310), 257 were no longer participating in FF4F but remained on the homestead, and 53 were permanently migrated to other provinces or countries. The attrition survey was completed with those that dropped out and remained on the homestead.

4.1.3.3 End-line survey results

The end-line survey results were analyzed using a per-protocol approach to show the impact of EHFP among those that have remained active in the project which may have introduced attrition bias. This approach was

taken as this was a scale-up study assessing the effectiveness of this program in real world settings and therefore better reflects program impact when adopted in an optimal manner. Further, with a dropout rate of 41.3%, employing an intent to treat analysis was not feasible as significant amounts of data would need to be imputed.

Time in the project was positively associated with horticulture production. Almost all households (96%) in the end-line sample had cultivated gardens compared to roughly 60% at baseline. Households with gardens produced twice as much vegetable varieties by end-line, and almost half of the surveyed population produced > 40 kg of vegetables (**Table 4**).

For the purposes of this study, women's empowerment was assessed across two dimensions, specifically, agriculture production and income use. Questions were adapted from IFPRI's Women's Empowerment in Agriculture Index (WEAI) tool, a validated measure used to assess women's autonomy and decision-making power across five dimensions: decisions about agricultural production, access to and decision-making power over productive resources, control over use of income, leadership in the community, and time use. According to this tool, the threshold for empowerment is 80% achievement across the five weighted indicators. Due to time constraints, we were unable to collect information on all dimensions and therefore couldn't calculate an empowerment index; however, we can infer that women in this sample were close to achieving empowerment on the two dimensions of interest even at baseline. Autonomy over food-crop farming, crops grown primarily for household consumption, however, did increase from 72% to 82% by end-line.

Water, sanitation and hygiene (WASH) indicators were examined to assess the uptake of BCC materials promoted throughout the project. Key messages included the benefits of utilizing improved sanitation and water facilities, and handwashing with soap during critical periods to prevent infection. Access to improved toilet facilities and water sources increased over time. Handwashing with soap was markedly high even at baseline; however, handwashing at certain times such as after attending soiled children remained low at end-line. This likely remained unchanged due to cultural beliefs that bodily waste from children is harmless, pointing to a need to revise BCC materials to dispel harmful beliefs.

Nutrition and health-related knowledge and practices were high among respondents even at baseline. Chief among nutrition messages promoted was exclusive breastfeeding of infants until six months of age. The majority of respondents, 83%, had knowledge of this even at baseline; however, it is unclear whether or not it is practiced as infant formula was widely used among respondents in the 24 HDR.

Household food security was measured using questions adapted from FANTA's household food insecurity access scale (HFIAS), a survey tool that captures both the occurrence and frequency of food insecurity episodes within the past 30 days. The mean (SD) HFIAS score of this sample was 4.08 (3.872) at baseline and decreased to 1.25 (2.464) by end-line. The prevalence of food insecurity decreased significantly such that almost 75% of surveyed households were food secure by end-line.

Anthropometric measurements were taken from the youngest child 6-59 months living in the home at the time of enrolment and the primary female caregiver 18-49 years of age at baseline and followed-up at end-line. There was no change in prevalence of stunting, wasting, or underweight among children over time.

Similarly, the proportion of women classified as underweight remained static. Due to the short duration of projects like FF4F, it is unsurprising that anthropometric measurements remained unchanged.

4.1.3.4 Attrition survey results

Attrition was defined as households that no were no longer receiving seed as of the last distribution round December 2017-February 2018 and were unable or unwilling to participate in the project. Based on this definition, 41% of the households revisited were classified as dropout. Among dropouts, 83% withdrew participation but remained on the homestead, and 17% permanently migrated away from the homestead. Certain patterns emerged with respect to dropout. The majority of households (80%) dropped out by the second round of seed distribution before any significant investments were made by themselves or the project. The reasons for dropout were also quite uniform across project areas and included: lack of time to dedicate to HFP; limited household labour; and pursuit of other income generating activities. Among households that permanently migrated away, 60% moved away to pursue other income generating opportunities. Additionally, dropout was most pronounced in Phnom Penh and Kampong Cham with 50% and 52% attrition respectively, and lowest in Kampot with 33% attrition. High attrition was expected in Phnom Penh due to proximity to alternative economic activities in the capital. Although alarming, the high dropout in Kampong Cham was expected due to a disease outbreak that delayed poultry distribution by as much as 4 months among villages in this province.

In addition to examining attrition patterns, we also sought to understand the extent to which EHFP promoted technologies, methodologies and practices were adopted by inactive households which are described in detail in the end-line report. In terms of production however, interesting similarities and differences emerged when active and inactive households were compared **(Table 5)**. Despite less than 5% of inactive households receiving poultry, nearly 80% raised poultry out of their own volition and produced outputs comparable to their active counterparts. Because of the overwhelming preference for poultry raising across project areas and among dropout households, future EHFP programming should refine and promote this model as a key intervention.

Although presented, we cannot draw strong conclusions about differences in aquaculture production as the percentage of inactive households engaged in this model was quite low, less than 10%. Among active households however, there were some trends that appeared. The majority of households self-selecting the EHFP+F model were from the coastal zone of Kampot where a high affinity for fish raising already existed. In contrast, no households in Phnom Penh self-selected this model likely due to the increased price of land in urban areas and availability of non-farm economic opportunities. Furthermore, small fish was harvested to a much lesser extent than large fish; approximately 30% of respondents with fishponds reported harvesting small fish compared to 60% harvesting large fish in the previous two months. This was likely due to a combination factors including low or inadequate fertilizer application and flooding which likely swept away small fish in greater proportions. Future EHFP programming can therefore be strengthened by including additional sessions on pond management and mitigating environmental constraints. Furthermore, because of the higher preference among households in coastal areas, the EHFP+F model is best suited and should be targeted as a key intervention in this agro-ecological zone.

In terms of horticulture production, time spent in the project was positively associated with increased volume of vegetable production and year-round production. Active households produced nearly twice as

much vegetable varieties in the past two months and harvested three times the amount of vegetables as inactive households. This was likely due to the large difference in the size of the garden area under cultivation where active households' gardens were approximately five times the size of inactive households.

In summary, enrolment in the EHFP intervention yielded highly positive results for those that remained engaged in the project. Improvements in agricultural production, household food security, and WASH were marked over time and are a testament to the program's potential to improve access to safe and nutritious food for rural households and the development of sustainable food systems.

4.1.4 FF4F spillover

In addition to capturing information on households currently engaged in the project and those that have dropped out, we also sought to capture the reach of EHFP through the '*spillover effect*'. Although spillover is difficult to measure with such a complex and dynamic project, based on program administrative data from our community sessions, we estimate that 15 non-target households within each target village (n=233) attended training, education, and/or demonstration events. In total, we estimate that n=3,496 non-target households received benefits from this project, thus benefiting an estimated n=17,480 family members overall. However, an assessment was not conducted to determine the extent non-targeted households adopted knowledge/techniques learned from the FF4F project. Further, while the CEA demonstrated that the FF4F program is cost-effective when implemented over a 10-year time horizon among targeted households, the calculated *spillover effect* suggests that the program benefits and reach may have been underestimated. This should be taken into consideration when evaluating the overall impact of the FF4F program and when comparing it to other nutrition-sensitive agriculture programs more broadly.

4.2 Objective 2: Develop and evaluate approaches for social impact investment models and training by women and men farmers to expand reach of EHFP

A major issue we found with FoF was high attrition and low beneficiary buy-in due in part to the cost-free approach and random assignment of participants to EHFP models. Keeping in line with objective two, we implemented a cost-sharing model in which beneficiaries were required to make financial contributions for inputs and allowed for self-selection of EHFP model type, based on needs and preferences. In using this approach, we have seen greater retention of participants and expanded the reach of the project to more geographically, ecologically and culturally diverse regions in Cambodia. We also adapted and refined the Nurturing Connections approach, first developed and implemented by HKI in Bangladesh. The following section describes the research results with respect to self-selection of EHFP models, the revisions that were made to the EHFP models and Nurturing Connections for the FF4F program, and the extent to which microcredit was used as a tool to help support households with the cost-sharing mechanism employed in FF4F.

4.2.1 Self-selection of EHFP model

During the targeting and recruitment stage, preference for EHFP only, EHFP+P, EHFP+F, and EHFP+F+P models were n=308, n=3,048, n=874, and n=1,112 respectively (**Table 6**). However, due to resource constraints, the project was only able to provide technical and input support to n=2568 households for EHFP only, n=1200 households for EHFP + P, and n=874 households for EHFP + F. Interestingly, we saw the greatest dropout in the EHFP only (33%) compared to 7% in the EHFP + P and 3% in the EHFP + F groups. This indicates that households are more likely to stay engaged in the EHFP program if some type of animal

husbandry is incorporated, even if it's not their first model of choice. Furthermore, the overall attrition rate in this phase of the project was 20.5% as compared to 38% in FoF suggesting that participation is strengthened when beneficiaries have a greater stake in investment and autonomy over interventions.[1]

4.2.2 Nurturing Connections for the Cambodian context

The FF4F gender strategy was informed and developed based on HKI's past experiences in EHFP and from the formative research conducted in the first six months of the project. From these learnings, we found the best fit for the program was the "Nurturing Connections" program, originally developed in Bangladesh. Between 2015-2018, Nurturing Connections was field tested, adapted and implemented in 2800 households in the FF4F program. Specifically, based on field staff feedback and insights from the gender analysis research, several revisions were made to ensure the manual was adapted appropriately for the local context. The content was updated to place greater emphasis on locally relevant gender issues, particularly women's autonomy in income expenditure and domestic abuse stemming from alcohol use. Additionally, all sessions were held in mixed group settings (both men and women) in Cambodia whereas in other more socially conservative settings, such as Bangladesh, sessions were often sex-segregated. Finally, the medium through which key messages were delivered were modified to include more exercises where participants illustrated and/or wrote responses rather than role played as the latter was perceived as childish among Cambodians.

The Cambodian curriculum is organized like the original version in that it is divided into four thematic areas: 1) Lets Communicate, 2) Understanding Perceptions and Gender, 3) Negotiating Power, and 4) Acting for Change. Within each theme, group exercises and/or discussions are facilitated by trained field staff on a bi-monthly basis at the community level and open to husband-wife pairs, elders, and community leaders. The number of sessions however, are reduced from nine to seven as peer group sessions (men or women only sessions) are eliminated. The first six community sessions focus on modules pertaining to the four themes, and the seventh and final session focuses on practical steps taken within the community to improve gender equality.

4.2.3 4th Nutrition Bulletin: impact of microcredit on HFP

Initially, we anticipated greater uptake of microcredit as a means of improving household access to participation in the FF4F project; however, as described in the fourth Nutrition Bulletin, uptake of microcredit for improving agricultural productivity was low. Microcredit opportunities were introduced to households participating in the FF4F project by Angkor Microcredit Kampuchea (AMK), with the intention of supporting ownership and entrepreneurship in EHFP activities through a unique cost-sharing model. Project participants, predominantly rural women farmers, were provided with access to microcredit and financial training by AMK. Despite targeted recruitment and community sensitization activities promoting microcredit, the percentage of households accessing loans from AMK remained relatively unchanged from baseline to end-line, 8% and 10% respectively. Furthermore, the percentage of households withdrawing loans or borrowing cash/in kind decreased by 16.2% from baseline to end-line, suggesting that microcredit may not be a preferred option to support EHFP activities among rural households. This is evidenced by the fact that only a quarter of respondents at end-line reported using loans towards agriculture inputs for horticulture, poultry or aquaculture production, and that an overwhelming majority (98%) reported using their own personal savings as the main source of cash contribution to participate in the FF4F program.

[1] Prokopy, 2005; Sara & Katz, 1998; Stein, 2001

When respondents did access loans, the most common ends to which they were used were towards stable assets such as land and transportation means, and building/renovating homes.

In addition to eliciting information on microcredit access and utilization, the nutrition bulletin also highlighted key information on household financial management. A key component of this project was the provision of the marketing and business entrepreneurship training for small-scale farmers to improve the profitability of HFP outputs and better predict market dynamics and trends. Despite concerted efforts to encourage uptake of business tools such as income/expense tracking, see fourth technical report, the percentage of respondents that maintained some form of record keeping for household income, expenditures, and loans, only increased by 4% between baseline and end-line and; the vast majority (74%) continued to rely on memorization as their predominant form of record-keeping. This lack up uptake of financial record keeping, and other business tools more broadly, points to a need to further refine business tools to be more cognizant of low literacy and limited comprehension of complex business concepts.

4.3 Objective 3: Scale up optimal models of EHFP with local and national governments, local and international NGOs, and private enterprise, promoting long term sustainability

As part of our efforts to develop optimal models of EHFP for scale-up in Cambodia and the Asia-pacific region, we held internal and external review workshops to standardize EHFP program tools, methodologies and implementation guidelines, and discuss pathways for vertical scale-up in national and regional nutrition and food security policy. In addition, HKI's EHFP training protocols were updated to reflect best practices and lessons learned throughout the scale-up of FF4F. The following section provides a short summary of these efforts with reference to annexes with further detailed information.

4.3.1 HFP knowledge exchange workshop

As previously discussed in section three of this report, HKI held a knowledge exchange workshop on their global EHFP program in Phnom Penh, Cambodia in January 2018. This workshop offered a unique opportunity for different HKI country offices to discuss experiences and lessons learned to further improve HKI's future EHFP projects. Specifically, HKI Cambodia discussed some of the key elements that have been critical to the success of the current FF4F program, including (i) an integrated program design that is grounded in an understanding of resource constraints and opportunities; (ii) EHFP model flexibility; (iii) VMFs that serve as a community resource; (iv) the inclusion of a package of essential nutrition actions, a multi-level behavior change and communication component; (v) promotion of gender equity; and (vii) linkages with existing systems, continuous learning for program improvement, and capacity enhancement of HKI and local NGOs and program beneficiaries. Furthermore, HKI teams from Vietnam and Myanmar, accompanied by government officials, visited the FF4F project areas to learn and see first-hand the experiences of project beneficiaries and implementing partners, and subsequently adapt and replicate best practices from FF4F program into the existing EHFP models in their country context. For example, both countries have implemented detailed production and market surveys using adapted tools and methods from the *Surveillance trial* in FF4F; specifically, about 600 ethnic minority households in mountainous northern Vietnam and 10,000 households in Ayerwaddy and Magwe, Myanmar, are using adapted production tracking tools developed for FF4F.

4.3.2 Updated guidelines for EHFP

During the implementation of the FF4F project, the project team updated key guidelines and protocols for different components of EHFP, which includes the Protocol for Establishing Fish Hatcheries (**Annex 12a**); Technical Guidelines for Targeting Households (**Annex 12b**); Technical Guidelines for Poultry Production (**Annex 12c**); ENA Manual for Trainers (**Annex 12d**); and the Nurturing Connections Training Manual (**Annex 12e**). These updated guidelines and manuals have been shared with stakeholders in Cambodia and the region to contribute to the scale up of different components of EHFP with interested stakeholders.

4.3.3 External annual project review workshop

The annual project review workshop was held in Buenos Aires, Argentina on October 18th, 2017 during the International Congress of Nutrition conference. We took advantage of this cost-saving measure as most members of our senior project management team and external advisory board were present at the conference. The purpose of the meeting was to review progress to date on project milestones and the broader implications of research findings beyond the lifespan of the project (see **Annex 13a** and **Annex 13b)** for the external advisory board meeting agenda and update, respectively). After brief remarks from our IDRC project officer, Dr. Annie Wesley, our discussion centred on the multitude of ways in which the FF4F project could make significant contributions to Cambodia's national food and nutrition security strategy. Additionally, we discussed the role of bilateral and multilateral donor agencies in facilitating the dissemination of research results more broadly, and the specific players needed to deploy relevant and applicable innovations to developing countries in order to make traction towards sustainable development goals. The detailed question guide along with a summary of the main discussion points are attached in **Annex 13c.**

4.4 Objective 4: use the evidence base to inform the national strategy for food security and national agriculture policy and contribute to nutrition and policies supported by national and international stakeholders

To address the fourth objective and limitations of the previous FoF research, the project team revised the FF4F research protocol to include a pragmatic effectiveness trial, called the S*urveillance trial*, in a subset of 654 households from the larger study sample. The following section describes the main findings from this trial. In addition, we provide an overview of the policy and advocacy work by the project partners in nutrition and a summary of research partnerships and spinoffs that are a direct results of the funding provided by IDRC and GAC.

4.4.1 24 HDR survey

A major limitation highlighted in the findings of the dietary assessment from FoF was that the data were collected during only the lean agriculture season (May/June) and it was thought that greater impact would be observed during the peak agricultural season (November/December). In addition, the lack of baseline dietary intake data in the FoF trial limited the conclusions that could be made from the results. Specifically, with no baseline data, we were not able to examine the change in dietary intake over time. To address these limitations, two rounds of 24 HDR surveys were conducted for the control and EHFP groups at the end of two growing seasons: the dry, lean season (May) and the rainy, harvest season (December). The primary aims of the 24 HDR surveys were to determine the impact of EHFP on the dietary intake and prevalence of inadequacy of key nutrients for women and children. The secondary aim was to examine differences in dietary intake for women and children during different growing seasons. As with the FoF trial, these 24

HDR surveys targeted young children (6-59) and WRA, defined in Cambodia as 15-49 y, mainly mothers, because of their high dietary requirements for cognitive development, growth, and reproduction. In total, n=42 clusters (villages) per group were randomly selected from the participating households in Kampot province (total n=654 households; n=336 control and n=318 EHFP groups). Kampot was selected as the study area as it is most representative of Cambodia's diverse agro-ecological zones and the respective diets associated with these different zones.

Prior to the roll-out of the 24 HDR surveys, the project team organized for Dr. Mourad Moursi from Harvest Plus to conduct an intensive workshop on best practices for conducting multiple-pass 24 HDR in resource-poor settings. This workshop not only provided us an opportunity for our continued commitment to local and international capacity and partnership building, but also allowed us to address and improve upon issues of under-reporting identified in FoF, which are common with dietary assessments. The following six points describe the improvements that were made to the study design and methods in an effort to reduce respondent recall biases and enable greater accuracy of data and interpretation of results for the FF4F project:

- Households were visited two days prior to the 24 HDR interview and were given and trained on the use of picture charts to track the foods/beverages consumed during the recall day as well as standard eating utensils (cups, bowls, plates, spoons) to assist in estimating portion sizes.

- The entire 24 HDR survey team were trained on standardized probes and prompts to obtain descriptive details about each food or drink recorded during the recall.

- The quantity of foods consumed was determined using different measurement methods (e.g. volume of food/beverages using dry rice or water, direct weight, weight of modelling clay and standard size). A food conversion factor database, with each measurement method, was compiled by the research team and supplemented with a database developed from a previous study by Harvest Plus in Mozambique and Uganda.[2]

- A recipe database was also developed by the research team through collecting and standardizing widely consumed household recipes.

- A food composition table was developed for the project that was compiled from seven sources[3], including a small sample of locally analysed Cambodian foods.

- Repeat recalls were collected on non-consecutive days from a subset (~20%) of the sample during all four 24 HDR surveys. Using the repeat recalls, sample intake distributions were adjusted, using the program PC-SIDE (version 1.0; Iowa State University), to remove within-individual variability in intake. This adjustment provided a more accurate estimate of usual intake of the study population.

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[2] Hotz C, Loechl C, De Brauw A, Eozenou P, Gilligan D, Moursi M, et al. A large-scale intervention to introduce orange sweet potato in rural Mozambique increases vitamin A intakes among children and women. British Journal of Nutrition 2012;108(1):163–76

[3] SMILING Database, ASEAN Database, INFOODS Database, Vietnamese Food Composition Database, Bangladesh Food Composition Table, USDA, Uganda FCT (Harvest Plus)

During all four 24 HDR rounds, data were collected on hard-copy questionnaires, then entered and processed in CS Dietary Pro (Serpro). Intakes of energy, fat, protein, iron, zinc, calcium, vitamin A, thiamin, and riboflavin for women and children during each season were summarized to identify intake distribution patterns and skewness. For each season, group differences (EHFP vs. control) in mean intake of the above-mentioned nutrients were tested using generalized linear mixed effect models with gamma distribution. The women's models were adjusted for the clustering effect, and the children's model were further adjusted for age and gender.

After statistical adjustment, we used the EAR cut-point method to estimate the prevalence of inadequacy for zinc, vitamin A, riboflavin, thiamin, and calcium in the population. That is, the continuous data for these nutrients were dichotomized into values above and below established EARs for a given nutrient, age (e.g. 6-11mo, 1-3y, 4-6y and 14-50 y) and life stage (e.g. lactating vs non-lactating women). Since there were very few pregnant women, these women were combined with non-pregnant women for analyses. Using the binary data, group differences in the prevalence of inadequate nutrient intakes during the lean and peak agriculture seasons were tested using a generalized linear mixed effect models with a logit link, controlling for clustering in the women's model, and controlling for clustering, age and gender in the children's model. For iron intake, the EAR cut-point method cannot be used to assess the prevalence of inadequacy because of its right skewed distribution. Instead, the full probability approach was used, where iron intakes were compared against iron requirement distribution percentiles and the probability of inadequate iron intake was calculated then treated as a continuous variable.

Of the n=654 women-child pairs enrolled in the *Surveillance trial*, n=279 and n=262 women and n=312 and n=305 children were available in the control group during the lean (May 2016) and peak (Dec 2016) agriculture seasons, respectively. For the EHFP group, n=211 and n=209 women and n=222 and n=218 children were available during the lean (May 2017) and peak (Dec 2017) agriculture seasons, respectively. Nutrient summaries from the 24 HDR analysis are presented in **Table 7** and **Table 8**. Among women and children, mean intakes of energy, protein, fat, iron, zinc, calcium, vitamin A, riboflavin, and thiamin did not differ between groups during either the lean or peak growing seasons. For both control and EHFP groups, white rice was the most important source of energy for women (range: 45%-47%) and children (range: 26%-32%), during both growing seasons. The second major source of energy for women and children was sweets/desserts (women: 13%-23%; children: 13%-23%) followed by Khmer vendor foods for women (range: 5%-7%) and milk/dairy products for children, particularly younger children, reflecting their consumption of commercial milk formulas (range: 4%-10%).

For both women and children, the estimated prevalence of inadequacy was high for most nutrients measured, except for riboflavin in women and children in the EHFP group. During the lean season, women in the EHFP group had significantly lower risk of prevalence of inadequacy for zinc, vitamin A, calcium, riboflavin, thiamin and iron compared to control (**Table 9**). There was a similar trend observed among children in the EHFP group during the lean season, with a lower risk of prevalence of inadequacy for all nutrients except calcium and iron, compared to control (**Table 10**). This difference in prevalence of inadequate intakes of nutrients in women and children was also captured during the peak agriculture season. Women and children were significantly less likely to have inadequate intakes of zinc, vitamin A, thiamin and riboflavin in the EHFP group versus control. These results suggest that the FF4F program was able to

improve nutrient intakes not only during the lean season, but throughout the year. More research into the food sources of nutrients is currently underway and will be published in a subsequent paper.

4..4.2 Cost-effectiveness analysis results

Importantly, while we were able to demonstrate that EHFP is feasible and acceptable for rural Cambodian households, we needed to determine the actual economic impact of the model at scale, particularly with respect to nutrition outcomes, in order to have stakeholder buy-in and ensure sustainability of the program beyond the funding cycle. The following section describes the methods and outcomes of the CEA and the importance of these findings with regard to food and nutrition policy in Cambodia.

The main challenge in conducting a CEA of the FF4F program was mapping the observed change in dietary intake to the number of DALYs averted. We chose to focus on zinc intake because zinc deficiency is high in Cambodian infants, with 33.7% having a zinc blood serum level of less than 7.65 micromoles per liter[4] and the FF4F intervention appears to increase dietary intake of zinc among children by a modest amount (12% in the lean season and 4% in the peak season).

For the CEA, we adapted the approach laid out by Stein et al.[5] to model the number of DALYs that would be averted by applying the FF4F intervention to a cohort of 1000 households over 10 years. The change in usual zinc intake was used to calculate an "efficacy factor" (***E***) for each child in our dietary intake study. ***E*** expresses the magnitude of adverse health outcomes averted due to the increase in intake as a proportion of the total adverse health outcomes attributable to zinc deficiency, and accounts for the non-linear relationship between intake and health outcomes. ***E*** was then used to adjust the incidence of four functional outcomes of zinc deficiency in children under 6y in our model: pneumonia, diarrhea, mortality, and stunting. The number of children at risk in each age category (<1, 1-2, 2-3, 3-4, 4-5, and 5-6) for each year of the model was estimated using the average number of children per FF4F household in Year 1 of the model. For subsequent years, the number of infants was estimated by multiplying the average number of women of reproductive age (age 15-44) per household (1.11) by the fertility rate (0.22 births per woman per year) for that demographic. Children in each age category moved into the next age category at each step of the model, until they aged out of the model, with each cohort being depleted based on the general mortality rate for that age group. The cohort of reproductive age women was depleted by the general adult mortality rate as well as 2.1% of the original cohort size (1107 women) at each step of the model, since women between ages 35 and 44, who would age out of the model by Year 10, represented 20.8% of the total number of women of reproductive age in the FF4F sample.

At each step of the model, the number of deaths among children as well as the number of cases of pneumonia, diarrhea, and stunting attributable to zinc deficiency were calculated using Stein et al.'s approach and weighted by the duration of the health outcome and the appropriate disability weight, if applicable, to calculate the total number of DALYs caused by zinc deficiency in that year (**Table 11**). In the

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[4] Wieringa FT, Dahl M, Chamnan C, et al. The High Prevalence of Anemia in Cambodian Children and Women Cannot be Satisfactorily Explained by Nutritional Deficiencies or Hemoglobin Disorders. Nutrition 2016; 8: 348.

[5] Stein AJ, Meenakshi JV, Qaim M, Nestel P, Sachdev HPS, Bhutta ZA. Analyzing the Health Benefits of Biofortified Staple Crops by Means of the Disability-Adjusted Life Years Approach: a Handbook Focusing on Iron, Zinc and Vitamin A. Washington, DC and Cali: International Food Policy Research Institute (IFPRI) and International Center for Tropical Agriculture (CIAT), 2005.

control scenario, the values in Table 11 were used to calculate DALYs, while in the intervention scenario, the incidence and mortality rates for the four functional outcomes of zinc deficiency were reduced by 23.4% based on the estimated value of ***E***. The net present value of total DALYs (using a 3% annual discount rate) for each scenario was calculated.

The net societal cost of implementing the FF4F program was estimated for each year of the program using the per-household monetized costs and value of production calculated in the cost-benefit analysis. To avoid double-counting the benefit produced by an increased production of zinc-rich foods, the value of the increase in production was reduced by 10%. The net societal cost for each year was calculated by subtracting the value of production from the costs, and the net present value of the net costs over 10 years was calculated by summing the time-discounted net costs in each year (using a 3% annual discount rate). The results of the cost-effectiveness model are provided in **Table 12.** The net monetary cost in both scenarios is negative, indicating that the value of agricultural production exceeded the cost of agricultural inputs in both groups. The incremental cost was also negative, indicating that the 1000 households in the intervention scenario would produce $315,617 worth of food more than the 1000 households in the control group over 10 years (or approximately $316 more per household over 10 years). In the intervention scenario, zinc deficiency was projected to result in 107.6 DALYs lost over 10 years for the 1000 intervention households, as compared to 140.3 DALYs in the control scenario, indicating that 32.7 DALYs would be averted per 1000 households by the FF4F intervention. Given that the FF4F intervention is estimated to both improve health outcomes and produce a positive net monetary benefit over a 10-year time horizon, the project appears to be highly cost-effective. Further, if the program is evaluated one nutrient at a time from a societal perspective and compared to other nutrition interventions that are thought to be highly cost effective (e.g direct supplementation or biofortification), it appears to be more cost-effective than alternative interventions due to the averted DALYs associated with deficiency in that nutrient and have negative incremental societal costs from increased agricultural production (results from CBA).

4.4.3 Policy and advocacy work

As the lead of Scaling-Up Nutrition - Civil Society Alliance in Cambodia, HKI plays a key role in coordination among civil society organizations and provides technical assistance to government ministries and institutions. During the reporting period, HKI has attended or presented at numerous national forums, workshops and conferences, including:

- National Workshop on WASH and Nutrition Integration chaired by the Deputy Prime Minister, H.E. Yim Chhay Ly, November 3, 2016 **(Annex 14**).
- Nutrition Sensitive Aquaculture Workshop in Siem Reap in December 2017 (see **Annex 15a** and **Annex 15b** for a copy of FF4F presentations).
- National Food Security Forum organized by CARD on June 28, 2017. See **Annex 16** for a copy of an oral presentation given by Cheng Chinneth and Ramona Ridolfi on the Nurturing Connections approach used in FF4F.
- IUNS 21st ICN in October 2017. See **Annex 17** for a copy of a presentation by Zaman Talukder on the role of small scale aquaculture and enhanced homestead food production in improving household food security and nutrition

- Assisted Royal Government of Cambodia to develop and finalize a concept note on National Nutrition Day Celebration (**Annex 18**).

- Showcased on FF4F products (small and large fish, vegetables, fruits, and processed food etc.) at the National Nutrition Day in Phnom Penh on November 2, 2017.

HKI has also continued to provide regular verbal updates on progress made and challenges faced by the FF4F project (especially the 24 HDR surveys, production surveillance, routine project monitoring, baseline survey and cost-share approach) to relevant government ministries, UN agencies, civil society organizations, and donor agencies. These updates were provided through national forums including the Technical Working Group for Agriculture and Water (TWG-AW), the National Nutrition Working Group (NWG), the National Food Security Forum (FSF), the Sub-Working Group on Nutrition and WASH (SWNW), and the Technical Working Group for Social Projection and Food Security and Nutrition (TWG-SP FSN).

Additionally, the FF4F team has already begun to use experiences and lessons learned from the FF4F project to inform and influence national policy and strategy. At the FF4F dissemination workshop, the project team proposed that the government and other stakeholders consider the following policy options:

Multi-sectoral National Strategy for Food Security and Nutrition 2019-2023: Although the current strategy highlights the importance of integrated interventions to improve food security and nutrition, it does not provide a concrete example of a successful model. We demonstrated that FF4F's integrated EHFP model increases food production, dietary diversity, food security and income among small-holder farmers. Therefore, we proposed that the FF4F model should be referred to in this next five year-strategy as a good example and a cost-effective model to improve dietary diversity and food security. CARD has responded positively to this request, and HKI will follow up during strategy development.

National Strategy on Fisheries: During the FF4F project, we demonstrated that with minimum input, rural households with existing ponds could be assisted to sustainably raise small and large fish in small ponds for household consumption and sale. Based our findings, we recommended that poly-culture is incorporated in FiA's national strategy as a means to improve food security and nutrition among small-holder farmers. As FiA has been intimately involved through both phases of the project, they have already taken steps to incorporate our poly-culture model into their next five-year national fisheries strategy.

Incorporating women's empowerment / gender equity into current policy and strategy on food security and nutrition: Women's empowerment / gender equity is inadequately addressed in the current national strategy for food security and nutrition. In the FF4F project, we demonstrated that by empowering women to take ownership of the farms, EHFP generated opportunities for women to improve their livelihoods and directly oversee household finances to benefit their family's wellbeing. We saw the percentage of women who were the primary decision makers regarding food crop farming choices increase by 10%, and at end-line, 79% of women were the primary decision-makers regarding major household expenditures. Therefore, we proposed to CARD and other stakeholders that women's empowerment should be more strongly considered in food security and nutrition policy as a means to improve food security and nutrition. HKI will follow up during strategy development.

4.4.4 Research partnerships and spinoffs

The funding provided through CIFSRF has led to additional funding from other organizations and has provided training for numerous highly qualified people. First, from the baseline evaluation of FoF, we learned that, contrary to expectations, the high rate of anemia in Cambodia was not due to iron deficiency but instead genetic haemoglobin disorders. As a follow-up to these findings and to determine the contribution of iron and other micronutrients to anemia in women of reproductive age, we conducted a trial entitled, "*The effect of oral iron with or without multiple micronutrients on hemoglobin concentration and hemoglobin response among non-pregnant Cambodian women of reproductive age: a 2 x 2 factorial, double-blind, randomized controlled supplementation trial"*. This study was funded by the Micronutrient Initiative ($153,000), CIHR ($240,000), and Sight and Life ($70,000 +$50,000 in kind). This formed Dr. Crystal Karackochuk's PhD and led to at least seven publications. Dr. Karackochuk is now an Assistant Professor at UBC and recently received $189,000 from CIHR to continue her work in iron research in Cambodia. Further, as a result of our findings, the Cambodian has government stopped routine weekly iron and folic acid supplementation in women of reproductive age. Second, through our CIFRSF project, we discovered a high rate of infantile beriberi, an often, fatal condition caused by a lack of thiamine in breast milk. As result we were awarded $112,000 from Grand Challenges Canada to conduct a study entitled, "*Fortified fish sauce as a means of combating infantile beriberi in rural Cambodia"*. In this study we showed that by providing fortified fish sauce to pregnant women we could increase breastmilk thiamine and infant blood thiamine levels. This formed the basis of Dr. Kyly Whitfield's PhD and led to four publications. Dr. Whitfield is now an Assistant Professor at Mount Saint Vincent University and was recently received a grant from the Bill and Melinda Gates Foundation through The Sackler Institute ($1,047,990) to explore salt fortification with iodine in Cambodia. Additionally, because of our CIFSRF involvement, we received ($60,000) from the University of Guelph to test the efficacy of Lucky Iron Fish©, an iron ingot, that is used when cooking and is meant to increase the iron levels in food. We found that the Lucky Iron Fish© was not effective in reducing anemia or iron deficiency. This research formed Aviva Rappaport's MSc thesis and led to three publications. Aviva is now at the Hospital for Sick Children, Toronto, working under Dr. Zulfiqar Bhutta in global health. Fourth, because of our success and experience in collecting blood samples and conducting dietary assessments in remote settings in Cambodia we were awarded a grant from Harvest Plus ($651,000) entitled, "*Micronutrient status indicators in women of childbearing age and their youngest children aged 6-59 months in the Democratic Republic of the Congo (DRC): A cross-sectional study*". This one-year study showed again that iron deficiency was not common in women of reproductive age or their young children in two provinces, South Kivu and Congo Central. This has led to three publications to date. Finally, because of our expertise in beriberi, we were awarded $65,000 to explore the reasons and solutions for a large outbreak of beriberi in Kiribati. In addition to the above-named researchers, CIFSRF has provided training for two other MSc trainees, three research assistants, and countless undergraduate nutrition, business, and public health students.

5. SYNTHESIS TOWARDS AFS THEMES

The following section highlights FF4F's key achievements in each of IDRC Agriculture and Food Security Program's key priority areas. In addition, we have developed an infographic highlighting the key findings of the project in relation to the AFS themes, which can be found in **Annex 19.**

5.1 Increasing agricultural productivity (Availability)

Despite a low awareness of sustainable agriculture, challenging climates and topography that's not conducive to farming, FF4F has helped more than 4500 households develop or improve a combination of vegetable gardens, poultry farms, and fishponds. Through provision of initial inputs, technical assistance, and training on sustainable agriculture, FF4F has contributed to the improvement of household gardening practices, creating more productive, resilient, and environmentally-friendly food systems.

The percentage of households with cultivated gardens increased form 61% at baseline to 96% by end-line and the vast majority have adopted improved gardening practices, including water and soil conservation, and appropriate fertilizer use. Over 80% of households with fishponds constructed their ponds in accordance to technical guidelines. To date, FF4F farms have contributed an estimated 28K kg of fish, 260K poultry eggs and 6M kg of fruit and vegetables to the local food supply. FF4F has also promoted 15 types of vegetables to farmers, thereby increasing crop diversity. This diversification of produce will help mitigate the impact of seasonality and create more resilient gardens. Furthermore, the creation of eight fish hatcheries and four nurseries have also contributed to a more secure food supply.

Long-term program sustainability will depend on the support of local leadership for EHFP and the transfer of program ownership to local institutions. To this end, we have established 232 Village Model Farms (VMFs) which serve as knowledge hubs for communities, mentoring households and disseminating information on environmentally safe farming practices. Many VMFs have successfully scaled up their farming activities and have become significant technical resources as well as strong motivators who encourage an entrepreneurial spirit to thrive in rural communities.

5.2 Improving access to resources, and/or markets and income (Accessibility)

FF4F has increased the gross incomes of participating households by an average of $285USD/year, providing a 10-year NMB of $477USD per household when compared to existing homestead production methods in place (base case). By the end of the project, more than half of the households were in Cambodia's fourth and highest wealth quintiles.

Another focal point of the FF4F project was to increase value-chain linkages. FF4F supported 12 entrepreneurial farmers in creating eight fish hatcheries and four nursing ponds that provided fingerlings to farmers and communities in two provinces. These were used as aquaculture inputs for the production of high value and value-added products like fish and preserved/processed fish products. Hatchery owners repaid the project by supplying fingerlings to the project households in year, producing more than 1.8M fingerlings to date, which accounts for 100% of the total supply required by project households. Between 2016-2017, fish hatchery owners earned a mean (range) net profit of $5,000 USD ($2,000 USD – $8,625 USD). Not only did this contribute to local economies and entrepreneurship, it created a closed-loop fish production system by providing a more stable supply of inputs used in the production of nutritious food. FF4F has also helped to find local suppliers for the other households, and established linkages with four poultry hatcheries, promoting the local production of chicks.

A series of business tools and initiatives have also been piloted and shown to improve crop selection decision-making, beneficiary financial planning, and market access. The crop tools have enabled beneficiaries to select crops that increase profits and reduce risk of loss, as well as plan crop seasons

according to the intensity of inputs required and nutritional value. Income and expense tracking has also increased motivation for households to continue HFP, as well as elevated the status of women in the family, as members come to realize how much the women have contributed to household finances. For households who wished to sell products, a price sharing board has improved market participation beyond the village level by providing a reference point for negotiation and timely information. Lastly, a strategic partnership with the microfinance institution AMK brought credit services to an estimated 750 households.

5.3 Improving nutrition (Utilization)

Stunting is common in Cambodia, particularly among rural smallholder farmers. By promoting EHFP, FF4F has increased dietary diversity for women and children, leading to higher micronutrient consumption in intervention versus control households. Specifically, the program has shown to reduce the prevalence of nutrient inadequacies for select nutrients, such as zinc, which are critical for growth, immunity, and preventing chronic undernutrition. Given the burden of zinc deficiency on an average child (144 DALYs lost), the increase in zinc intake as a result of the program has the potential to avert 32.7 DALYs per 1000 households, translating into a net monetary benefit of $315,671USD.

Ultimately by the end of the project, 72% of households were considered 'food secure', and the mean HFIAS score decreased by 2.8 from baseline to end-line. Further training on WASH has increased the number of households using an improved water source and sanitation facilities by 14%, and increased uptake of handwashing with soap by 11%. Through Essential Nutrition Actions (ENA) training, more women were able to correctly identify food sources rich in iron (90% overall by end-line) and vitamin A (62% overall by end-line), enabling them to make better food choices for themselves and their families.

Women are crucial actors in breaking the poverty cycle and influencing the health of the entire household. By empowering women to take ownership of the farms, HFP generated opportunities for women to improve their livelihoods and directly oversee household finances to benefit their family's wellbeing. FF4F saw the percentage of women who were the primary decision makers regarding food crop farming choices increase by 10%, and at end-line, 79% of women were the primary decision-makers regarding major household expenditures. FF4F also launched a gender strategy and training material specific to Cambodia and organized husband-wife workshops on power relations, domestic violence, asset control and other gender-related issues, reaching a total of 2,878 men and 3,934 women. A combination of the income from FF4F and gender workshops translated into females having greater decision-making power both regarding the garden and with expenses, thereby slowly dismantling underlying gender inequities.

5.4 Informing policy

Results on the efficacy of using FF4F's EHFP models to improve incomes, achieve greater dietary diversity, improve nutrition and findings on its scalability and feasibility in geographically diverse regions have the potential to be highly influential for stakeholders interested in agriculture, food and nutrition, and development. FF4F has produced publications in peer-reviewed journals and continues to share learnings at forums and workshops in various arenas, including academia, government ministries, UN agencies, civil society organizations, and donor agencies. Additionally, project findings were shared at several high level international forums, including the 2016 Micronutrient Forum, Experimental Biology conference in 2016, and the 2017 International Congress on Nutrition Conference. On a national level, FF4F has continued to work alongside government and NGO-led working groups to influence national policies in food security

and agriculture, led the Scaling Up Nutrition (SUN) movement in Cambodia, and established steering committees to promote civic engagement and ensure sustainability of the project.

A dietary food composition database has been created detailing nutrient values for commonly consumed Cambodian foods that will be highly valuable to health civil society groups and the Cambodian government. FF4F has been active in sharing knowledge at the international, regional, and national level and contributes regularly in meetings with the National Food Security Forum, the Sub-working Group on Nutrition and WASH, and the Technical Working Group for Social Protection and Food Security and Nutrition. A policy brief summarizing key findings and recommendations from FF4F has been drafted and will impact Cambodia's National Nutrition and Food Security strategy.

In the agricultural sector, FF4F has contributed its core EHFP innovation which includes three models (a mix of gardens, fish ponds, and poultry farms), training, VMFs, and other innovative methods and technologies for sustainable agriculture. FF4F continues to share progress and findings with the Cambodian Technical Working Group for Agriculture and Water. Ultimately, HKI will work closely with the government ministries to incorporate best practices of EHFP into Cambodia's National Agriculture Policy.

6. PROJECT OUTPUTS

FF4F's communication strategy was developed with consideration to dissemination not only across the life of the project but beyond, all while ensuring all project outputs were freely and widely available. To this end, project outputs have been produced and disseminated using a wide array of medium, including international and national presentations, peer-reviewed journal publications, nutrition bulletins, print and social media, and workshops. Research findings will continue to be published beyond the end of the project funding period, thereby extending the influence of the project results with key stakeholders in Cambodia and elsewhere. The following is a brief summary of project outputs produced during the 3-year project life-cycle. A more detailed list of titles and authors of publications and presentations can found in **Annex 20**.

Nutrition bulletins: Four nutrition bulletins have been produced during the FF4F project summarizing the market and business research, scale-up research strategy, insights into sustained EHFP production for the FoF trial households, and the impact of microcredit as a tool for increasing the availability of financial resources for participation in the FF4F program. The bulletins were distributed among key stakeholders, including community project participants; field staff; project partners; civil society; United Nations agencies; NGOs; government ministries; donors; private sectors; academies; and local and international universities.

Workshops, forums and meetings: The project team has continuously raised the national and international profile of the FF4F project by actively participating in national working groups, forums and presenting at national and international food and nutrition security conferences. HKI was also nominated to be the focal point for the SUN movement in Cambodia. In this capacity, HKI has played a key role in coordination of civil society organizations and provided technical assistance to government ministries and institutions.

Policy brief: Results from the FF4F project are used to advocate for policy change at the national level. Information on the potential solutions to food insecurity, undernutrition and gender inequalities in Cambodia are presented in a policy brief and will be shared with key government ministries (e.g. the

Fisheries Administration, Ministry of Health, Ministry of Rural Development and Agriculture) and influence Cambodia's national strategy for years to come.

Media: Many of the FF4F outcomes and activities have been reported on in Cambodian and Canadian news outlets, through social media such as Twitter and the project website, through video clips and outcome stories on YouTube, and using print media such as posters and infographics. These channels have proven to be an effective means to share FF4F information and results with the general public.

BCC and training materials: During FoF, the project partners developed numerous BCC materials on improved EHFP practices, polyculture, nutrition, and women's empowerment, which were used for training and educational purposes and distributed to project participants, NGO staff, and government. These materials were refined and revised in FF4F, including the Nurturing Connections manual (**Annex 21**), and the aquaculture protocol. Additionally, new materials on best practices for poultry production and dietary assessments were developed and distributed during FF4F.

7. PROBLEMS AND CHALLENGES

The project encountered challenges, as reported in each of the previous technical reports. The following is a summary of the main issues that were faced during the project as a whole.

During the initial stages of project implementation (first and second round of seed distribution) we faced challenges with poor quality of seed varieties, inability of households to meet cost-sharing requirements, delays in procurement of inputs from our distributors, and a poultry disease outbreak, which lead to early drop out. We addressed some of these challenges by changing seed suppliers, reducing the cost-sharing component to 30%, and replacing households that dropped out on or before the second round of seed distribution. Additionally, the collection of cash contributions for seeds was a challenge due to the time required for staff to collect the contribution, as project staff often needed to visit households several times to secure the cash.

As is common in research projects in resource limited settings, we faced issues with high turnover of field staff that directly supported project households, especially nearing the end of the project. This resulted in challenges with respect to quality of training received by project households, as new staff would often experience lag time in gaining the skills and knowledge required to support households, which may have had a negative impact on households' engagement with the project leading to dissatisfaction or dropout. In future projects, HKI will explore incorporating end-of-contract bonuses or similar mechanisms to improve staff retention.

Participation by men in the Nurturing Connections sessions was initially very low (2%). Men were less available than women during the daytime, as they tend to move outside of the household/community during the daytime for work related activities. There was also a perception among men that this activity was oriented towards women only. To address this, HKI worked with project officers to find solutions to increase male participation. Specifically, men were invited more directly – instead of requesting households to participate, men were invited by name; and the timing of sessions and location of sessions were adjusted to suit men's schedules. These actions led to a 40% increase in participation among men.

During project implementation, the Cambodian government requested results on nutrition indicators from FF4F project, including (i) minimum dietary diversity in women, (ii) minimum dietary diversity for children; (iii) minimum acceptable diet, and (iv) rate of exclusive breastfeeding. However, our baseline and end-line surveys did not include these indicators. To address the government's request, HKI incorporated these indicators in the last round of project monitoring and shared the data with the government.

Finally, and most importantly, we encountered challenges with meeting our original completion date of March 31, 2018, due to constraints presented by the timing of data availability and the magnitude and complexity of analysis required within the project cycle. Thankfully, we were granted a no-cost extension by IDRC, which allowed us to retain employees to complete the main outcome analysis.

8. OVERALL ASSESSMENT AND RECOMMENDATIONS

We are grateful to IDRC and GAC for providing us with financial resources and support to be able to conduct the first ever randomized controlled trial testing the efficacy of HFP and then allowing us to test the scalability of different models of HFP in diverse agro-ecological zones. We are especially grateful to Annie Wesley as our project manager for her support over the course of both phases. We feel that both phases of our project have yielded a wealth of data with implications for Cambodia's future food and nutrition security strategy and for the global community.

As we have noted in our challenges section above, we feel that a revision of timelines for research and development projects would alleviate some of the constraints that we have faced. From a UBC perspective we faced a number of challenges relating to loss of investigators, including the PI to Australia. Fortunately, we were able to employ two excellent research associates. These CIFSRF projects require a large 'in kind' contribution from the Canadian universities to pay investigator (faculty) salaries. For Tri-Council, indirect costs are not included in the applications but are bulk paid to the university based on the total value of the grants through the Canadian Research Support Fund which totalled $30,000,000 last year for UBC or roughly a 25-30% indirect. Reporting requirements have been streamlined and now take less time than the beginning but are still more time consuming than for other funding agencies. Unfortunately, this takes away from other important outputs such as publication in scientific journals especially at the end of the grant period when data becomes available. In the future IDRC might want to consider setting aside a portion of funds for programs that could be applied for after the end-line report, to allow effective dissemination of findings not just through scientific journals but by other means that will ensure maximum uptake.

9. LIST OF ANNEXES

Annex 1: Fourth Nutrition Bulletin

Annex 2: Draft CBA publication presented to VanHem

Annex 3a: End-line Survey Tool

Annex 3b: End-line Survey Protocol

Annex 3c: End-line Survey Report

Annex 4a: Dissemination Workshop Participation List

Annex 4b: Dissemination Workshop Report

Annex 5: Updated Aquaculture protocol

Annex 6a: Results of Midterm Review of NSFSN

Annex 6b: NSFSN Midterm Review Presentation

Annex 7: Policy Brief

Annex 8a: MCN Submitted Manuscript

Annex 8b: Global Health Science and Practice Submitted Manuscript

Annex 8c: Draft Publication on Dietary Intake of Women and Children in FF4F

Annex 9: EHFP Knowledge Exchange Workshop Report

Annex 10: Aquaculture Research Report

Annex 11: Attrition Survey Tool

Annex 12a: Updated Protocol and Technical Guidelines for Hatcheries

Annex 12b: Updated Targeting Manual

Annex 12c: Updated Small-Scale Poultry Production Manual

Annex 12d: Updated ENA Facilitators Guide

Annex 12e: Updated Nurturing Connections Training of Trainers Guide

Annex 13a: External Advisory Board Meeting Agenda

Annex 13b: External Advisory Board FF4F Update

Annex 13c: Annual Project Review Workshop Summary

Annex 14: National Workshop on WASH and Nutrition Integration Presentation by Hou Kroeun

Annex 15a: Global Aquaculture Workshop Oral Presentation by Hou Kroeun

Annex 15b: Global Aquaculture Workshop Poster by Sok Hoing Ly

Annex 16: 62nd Food Security Forum Nurturing Connections Presentation by Cheng Chinneth and Ramona Ridolfi

Annex 17: IUNS Oral Presentation by Zaman Talukder

Annex 18: National Nutrition Day 2017 Concept Note

Annex 19: AFS Themes Infographic

Annex 20: List of FF4F Communication Outputs

Annex 21: Nurturing Connections Manual

10. TABLES

Table 1. Cost Benefit Analysis with 10-Year Time Horizon

	Control Group		EHFP Group	
Year	**Cost (USD)**	**Production (USD)**	**Cost (USD)**	**Production (USD)**
1	346.48	808.69	514.87	905.85
2	336.39	785.14	456.71	973.79
3	326.59	762.27	443.41	945.43
4	317.08	740.07	430.50	917.89
5	307.85	718.51	417.96	891.89
6	298.88	697.59	405.78	865.20
7	290.17	677.27	393.97	840.00
8	281.72	657.54	382.49	815.54
9	273.52	638.39	371.35	791.78
10	265.55	619.80	360.53	768.72
Total	**3,044.24**	**7,105.26**	**4,177.57**	**8,715.36**

Incremental Cost = 1,133.33 USD

Incremental Benefit = 1610.09 USD

Incremental Net Benefit = 476.77 USD

Table 2. Household Survey Sample Information

Survey	Planned sample size	Actual sample size	% non-respondent	Main reasons for non-respondent
Baseline	n=1087	n=1087	n/a	n/a
End-line	n=751	n=407	41.3%	Migration for alternative income generating activities
				Not enough time
				Not enough labour

Table 3. Average Homestead Food Production Across Months and Between Groups

	Control Group							EHFP Group						
Month	**Veg (kg), mean (SD)**	**Fruit (kg), mean (SD)**	**Small Fish (kg), mean (SD)**	**Large Fish (kg), mean (SD)**	**Poultry mean (kg), mean (SD)**	**Poultry Eggs (units), mean (SD)**	**Birds (units), mean (SD)**	**Veg (kg), mean (SD)**	**Fruit (kg), mean (SD)**	**Small Fish (kg), mean (SD)**	**Large Fish (kg), mean (SD)**	**Poultry mean (kg), mean (SD)**	**Poultry Eggs (units), mean (SD)**	**Birds (units), mean (SD)**
May	19.4 (63.7)	72.4 (115.7)	0.3 (1.5)	1.4 (5.5)	10.9 (13.7)	13.2 (53.5)	8.4 (14.3)	37.8 (84.3)*	62.6 (116.5)	1.1 (4.2)*	4.3 (10.9)*	10.9 (11.8)	16.9 (17.7)*	13.4 (13.3)*
June	13.8 (26.4)	78.8 (158.1)	0.5 (4.0)	1.0 (4.3)	6.8 (9.5)	10.6 (14.5)	7.4 (11.4)	35.8 (97.2)*	68.2 (89.6)	0.6 (2.1)*	1.8 (4.0)*	5.9 (8.1)	12.5 (14.6)	11.2 (14.6)*
July	20.1 (83.6)	21.5 (50.2)	0.2 (1.2)	0.4 (1.9)	5.2 (7.9)	8.7 (15.2)	8.2 (15.3)	20.7 (53.8)	59.6 (89.8)*	0.4 (1.5)*	1.3 (4.3)	6.4 (7.6)*	11.7 (13.6)*	10.9 (13.2)*
August	25.1 (61.6)	23.9 (71.8)	0.1 (0.7)	0.2 (1.1)	5.5 (6.9)	7.8 (13.5)	11.0 (16.3)	32.4 (68.2)	47.1 (69.6)*	0.4 (1.5)*	1.3 (4.4)*	7.0 (8.6	11.4 (13.9)*	9.7 (11.2)
Sept	24.4 (48.2)	24.3 (55.4)	0.1 (0.8)	0.3 (1.5)	7.1 (10.5)	11.7 (14.0)	10.8 (13.7)	27.1 (66.4)	52.3 (77.1)*	0.3 (1.4)*	1.0 (4.8)*	5.9 (7.3)	12.3 (14.8)	11.1 (14.8)
Oct	18.4 (28.4)	20.0 (34.4)	0.1 (0.6)	0.2 (1.3)	8.6 (10.5)	11.0 (14.5)	11.8 (15.1)	27.3 (57.3)	55.1 (92.4)*	0.2 (1.0)*	1.0 (4.0)*	9.2 (10.0)	10.6 (14.9)	10.6 (12.4)
Nov	22.2 (43.8)	18.6 (47.3)	0.03 (0.5)	0.2 (1.0)	5.7 (8.9)	8.6 (14.5)	10.0 (14.6)	29.5 (80.6)	47.5 (85.5)*	0.2 (1.1)*	0.5 (1.7)*	4.4 (7.8)	8.3 (12.9)	9.0 (12.0)
Dec	23.9 (62.8)	21.2 (44.9)	0.05 (0.4)	0.4 (2.7)	6.4 (12.8)	13.9 (18.2)	9.7 (14.6)	32.7 (91.6)	56.4 (119.3)*	0.2 (0.7)*	0.7 (2.1)*	4.2 (9.2)*	16.4 (22.1)	9.8 (17.5)
Jan	25.2 (76.2)	21.6 (38.9)	0.06 (0.5)	0.4 (3.0)	4.8 (7.6)	15.2 (18.5)	13.9 (17.0)	22.0 (53.7)	51.0 (95.1)*	0.3 (1.2)*	0.8 (2.5)*	4.9 (6.6)	16.8 (21.4)	14.0 (20.0)

* Indicates statistically significant difference between EHFP and control groups ($p < 0.05$) from Wilcoxon rank-sum test adjusted for clustering

Table 4. Summary of Key Indicators for Active Households

Key Indicators	Baseline	End-line
HH with home gardens	61%	96%*
Number of vegetable varieties grown in past two months [median (range)]	3(1-14)	7(1-30)*
HH harvesting <15 kg in past two months	54%	26%*
HH harvesting >40 kg in past two months	28%	48%*
WRA primary decision in food-crop farming	72%	82%*
HH with improved drinking water source during dry season	48%	62%*
HH with improved toilet facilities	66%	80%*
HH handwashing with soap	85%	96%*
Handwashing after attending soiled child	14%	19%
Primary caregiver aware of exclusive breastfeeding until 6 mos.	83%	86%
Mean HFIAS score [mean ± SD]	4.08±3.872	1.25±2.464*
HH food secure	26%	72%*
Women: Underweight	11%	13%
Children: Stunted	27.6%	26%
Children: Underweight	24%	25%
Children: Wasted	8%	9%

*Indicates $p<0.05$

Table 5. Comparison of Active vs. Inactive Households

Key Indicators	Inactive HH	Active HH
HH with home gardens	72%	96%
Garden area under cultivation (m^2)	10(2-900)	50(2-4000)
Number of vegetable varieties grown in past two months [median (range)]	4(1-17)	7(1-30)
Kilograms of vegetables produced in past two months [median (range)]	12 (0.20-765)	37 (0.10-2124)
HH engaged in year-round production (9-12 months)	25%	55%
HH engaged in aquaculture production	8%	33%
Kg of small fish harvested in past two months [median (range)]	0 (0-15)	0(0-20)
Kg of large fish harvested in past two months [median (range)]	0.08 (0-290)	2(0-200)
HH engaged in poultry raising	77%	92%
No. of chicken eggs produced in past two months	25(0-200)	30(0-185)
No. duck eggs produced in past two months [median (range)]	0(0-810)	0(0-1200)

Table 6. Retention of Households Based on Self-Selected EHFP Models

	EHFP only	**EHFP+P**	**EHFP+F**	**EHFP+F+P**	**% dropout**	**Main reasons for dropout**
Household preference	n=308	n=3,048	n=132	n=1, 112	n/a	n/a
Project enrollment (n=4600)	n=2526, 55% of total sample size	n=1200, 26% of total sample size	n=874, 19% of total sample size	n=0	n/a	n/a
Project completion (n=3656)	n=1700	n=1112	n=844	n/a	20.5%	i) inadequate labour ii)limited access to adequate irrigation issues iii) diminished interest in HFP

Table 7. Difference in Women's Nutrient Intake by Season and Group

	CONTROL GROUP ***(n=279)***		**EHFP GROUP** ***(n=211)***		**PROGRAM IMPACT (EHFP *vs* CONTROL)**			
	Lean Agriculture Season (May 2016) mean (SD) *n=279*	Peak Agriculture Season (December 2016) mean (SD) *n=262*	Lean Agriculture Season (May 2017) mean (SD) *n=211*	Peak Agriculture Season (December 2017) mean (SD) *n=209*	Lean Agriculture Season (May 2017 *vs* May 2016) Mean Ratio (95%CI)	p-value	Peak Agriculture Season (December 2017 *vs* December 2016) Mean Ratio (95%CI)	p-value
Energy (kcal/d)	2241.9 (819.9)	2299.1 (825.1)	2372.2 (804.1)	2405.7 (915.8)	1.01 (0.85, 1.18)	0.980	1.05 (0.98, 1.20)	0.187
Protein (g/d)	77.9 (31.6)	76.8 (29.4)	74.4 (27.6)	79.5 (30.1)	0.93 (0.78, 1.10)	0.411	0.97 (0.96, 1.11)	0.339
Fat (g/d)	46.2 (25.9)	44.7 (27.4)	41.2 (24.2)	47.2 (28.5)	0.84 (0.67, 1.05)	0.122	1.06 (0.95, 1.18)	0.335
Calcium (mg/d)	551.7 (436.7)	534.4 (349.1)	515.9 (269.8)	559.3 (355)	0.89 (0.69, 1.15)	0.371	1.05 (0.94, 1.17)	0.364
Iron (mg/d)	13.3 (6.5)	12.9 (6.4)	14 (8.3)	13.1 (6.7)	1.01 (0.81, 1.26)	0.930	1.01 (0.93, 1.11)	0.775
Zinc (mg/d),	8.6 (9.3)	7.8 (3.8)	8 (5.3)	8.3 (3.9)	0.93 (0.75, 1.16)	0.513	1.06 (0.97, 1.17)	0.193
Thiamin (mg/d)	1.2 (0.6)	1.1 (0.5)	1.3 (0.5)	1.1 (0.6)	1.06 (0.87, 1.29)	0.570	1.05 (0.97, 1.14)	0.257
Riboflavin (mg/d)	1.8 (1.5)	1.6 (1.3)	1.6 (1.2)	1.7 (1.3)	1.28 (0.94, 1.74)	0.117	1.08 (0.94, 1.24)	0.257
Vitamin A (RAE/d)	680.1 (2264.1)	426.6 (540)	596.7 (843.7)	633.1 (1665.4)	1.67 (0.64, 4.37)	0.298	1.47 (1.00, 2.17)	0.050

Table 8. Difference in Children's Nutrient Intake, by Season and Group

	CONTROL GROUP *(n=279)*		EHFP GROUP *(n=211)*		PROGRAM IMPACT (EHFP *vs* CONTROL)			
	Lean Agriculture Season (May 2016)	Peak Agriculture Season (December 2016)	Lean Agriculture Season (May 2017)	Peak Agriculture Season (December 2017)	Lean Agriculture Season (May 2017 vs May 2016)		Peak Agriculture Season (December 2017 vs December 2016)	
	mean (SD) *n=312*	mean (SD) *n=305*	mean (SD) *n=222*	mean (SD) *n=218*	Mean Ratio (95%CI)	p-value	Mean Ratio (95%CI)	p-value
Energy (kcal/d)	1092.3 (506.1)	1216.7 (487.5	1193.3 (524.3)	1272.7 (510.6)	1.02 (0.95, 1.10)	0.531	0.98 (0.91, 1.05)	0.500
Protein (g/d)	32.4 (17.8)	35.3 (16.1)	35.6 (17.4)	38.1 (15.4)	1.01 (0.93, 1.10)	0.824	0.99 (0.92, 1.07)	0.775
Fat (g/d)	33.3 (18.4)	31.2(16)	29.1 (14.4)	29.9 (16.0)	0.92 (0.83, 1.01)	0.091	0.99 (0.89, 1.09)	0.809
Calcium (mg/d)	346.9 (282.1)	355.8 (242.8)	346 (239.4)	337.2 (231.6	1.05 (0.93, 1.19)	0.395	0.97 (0.86, 1.09)	0.574
Iron (mg/d)	6.1 (4.5)	6.7 (4.3)	6.9 (4.4)	7 (4.0)	1.04 (0.93, 1.18)	0.480	0.97 (0.87, 1.07)	0.521
Zinc (mg/d),	4.4 (12.1)	4 (2.3)	4.1 (2.4)	4.3 (2.1)	0.89 (0.65, 1.22)	0.461	1.01 (0.91, 1.10)	0.989
Thiamin (mg/d)	0.5 (0.3)	0.6 (0.3)	0.6 (0.4)	0.6 (0.3)	1.12 (1.02, 1.23)	0.013	0.99 (0.91, 1.09)	0.996
Riboflavin (mg/d)	0.8 (0.7)	0.9 (0.7)	1 (0.9)	0.9 (0.7)	1.21 (1.04, 1.41)	0.016	1.03 (0.89, 1.19)	0.7003
Vitamin A (RAE/d)	408.6 (1379.5)	406.5 (1578.6)	345.5 (439.5)	438.3 (1238.7)	0.87 (0.54, 1.40)	0.569	1.13 (0.66, 1.95)	0.654

Table 9. Difference in Prevalence of Inadequate Nutrient Intakes Among Women Aged 19-49y, by Season and Group

	CONTROL (n=279)		EHFP (n=211)		PROGRAM IMPACT (EHFP *vs* CONTROL)			
	Peak Agriculture Season (December 2016)		Lean Agriculture Season (May 2017)					
	n=279	***n=262***	***n=211***	***n=209***	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Zinc, n (%)	71 (25.5%)	72 (27.5%)	34 (16.1%)	19 (9.1%)	0.51 (0.29, 0.88)	0.015	0.22 (0.11, 0.41)	<0.001
Vitamin A, n (%)	159 (57.0%)	156 (59.5%)	82 (38.9%)	94 (45.0%)	0.45 (0.29, 0.72)	0.001	0.54 (0.34, 0.86)	0.009
Calcium, n (%)	251 (90.0%)	239 (91.2%)	211 (100%)	197 (94.3%)	—	—	—	—
Riboflavin, n (%)	56 (20.1%)	37 (14.1%)	12 (5.7%)	15 (7.2%)	0.24 (0.13, 0.46)	0.001	0.47 (0.25, 0.88)	0.019
Thiamin, n (%)	108 (38.7%)	119(45.4%)	32 (15.2%)	45 (21.5%)	0.20 (0.08, 0.49)	0.001	0.24 (0.18, 0.33)	0.001
Iron, mean probability	(59.0%)	(62.0%)	(52.1%)	(60.1%)	0.89 (0.81, 0.97)	0.001	0.97 (0.90, 1.05)	0.439

Notes: Prevalence of inadequacy was estimated as the percent of the usual intake distribution below the EAR for each nutrient other than iron. For iron, the full probability method was used and probability of inadequacy was assessed based on 10% bioavailability (Gibson & Ferguson, 2008). EARs for lactating/non-lactating women from Allen et al. 2006 Table 7.2 with the exception of zinc; zinc EARs from Hotz, 2007, Table 4. '*mixed or refined vegetarian diet'*. For iron, the full probability method was used and probability of inadequacy was assessed based on 10% bioavailability (Gibson & Ferguson, 2008).

Table 10. Difference in Prevalence of Inadequate Nutrient Intakes Among Children Aged 6-59mo, by Season and Group

	CONTROL (n=312)		**EHFP (n=222)**		**PROGRAM IMPACT (EHFP *vs* CONTROL**			
	Lean Agriculture Season (May 2016)	Peak Agriculture Season (December 2016)	Lean Agriculture Season (May 2017)	Peak Agriculture Season (December 2017)	Lean Agriculture Season (May 2017 vs May 2016)		Peak Agriculture Season (December 2017 vs December 2016)	
	n=312	*n=305*	*n=222*	*n=218*	OR (95% CI)	p-value	OR (95% CI)	p-value
Zinc, n (%)	98 (31.4%)	44 (14.4%)	37 (16.7%)	10 (4.6%)	0.49 (0.32-0.75)	0.001	0.32 (0.15-0.64)	0.002
Vitamin A, n (%)	189 (60.1%)	220 (72.1%)	116 (52.3%)	129 (59.2%)	0.60 (0.39-0.92)	0.020	0.46 (0.29-0.72)	0.001
Calcium, n (%)	241 (77.2%)	229 (75.1%)	190 (85.6%)	178 (81.7%)	1.63 (0.88-3.01)	0.119	1.34 (0.74-2.41)	0.335
Riboflavin, n (%)	51 (16.4%)	35 (11.5%)	15 (6.8%)	1 (0.5%)	0.34 (0.18-0.64)	0.001	0.03 (0.01-0.24)	<0.001
Thiamin, n (%)	125 (40.1%)	77 (25.3%)	48 (21.6%)	31 (14.2%)	0.36 (0.22-0.60)	<0.001	0.47 (0.27-0.82)	0.008
Iron, mean probability	(58.6%)	(50.0%)	(53.0%)	(49.9%)	0.92 (0.81-1.05)	0.231	1.02 (0.89-1.16)	0.814

Notes: Prevalence of inadequacy was estimated as the percent of the usual intake distribution below the EAR for each nutrient other than iron. For iron, the full probability method was used and probability of inadequacy was assessed based on 10% bioavailability (Gibson & Ferguson, 2008). EARs for lactating/non-lactating women from Allen et al. 2006 Table 7.2 with the exception of zinc; zinc EARs from Hotz, 2007, Table 4. '*mixed or refined vegetarian diet'*. For iron, the full probability method was used and probability of inadequacy was assessed based on 10% bioavailability (Gibson & Ferguson, 2008).

Table 11. Parameters Used in Cost-Effectiveness Model for 1000 Households

Functional outcomes	Target groups	Annual incidence rate	Proportion of incidence attributable to zinc deficiency	Duration of illness/ remaining life expectancy	Disability weights
Diarrhea	Infants <1y	4.68 cases per child[a]	0.18[b]	3 days [b]	0.20[b]
	Children 1-5y	3.27 cases per child[a]	0.18[b]	4 days[b]	0.15[b]
Pneumonia	Infants <1y	1.18 cases per child[a]	0.41[b]	4 days[b]	0.30[b]
	Children 1-5y	1.55 cases per child[a]	0.41[b]	4 days[b]	0.20[b]
Stunting	Infants <1y	337 cases per 1000 live births[a, b]	1.00[b]	68.65 y[c]	0.001[b]
Mortality	Infants <1y	28 deaths per 1000[a]	0.04[b]	68.65 y[c]	n/a
	Children 1-5y	1.76 deaths per 1000[a]	0.04[b]	69.40 y[c]	n/a
	Women 15-44y	1.64 deaths per 1000[c,d]	n/a	n/a	n/a

[a] ICF International. Cambodia Demographic and Health Survey 2014. Rockville, Maryland: ICF International, 2014.
[b] Stein AJ, Meenakshi JV, Qaim M, Nestel P, Sachdev HPS, Bhutta ZA. Analyzing the Health Benefits of Biofortified Staple Crops by Means of the Disability-Adjusted Life Years Approach: a Handbook Focusing on Iron, Zinc and Vitamin A. Washington, DC and Cali: International Food Policy Research Institute (IFPRI) and International Center for Tropical Agriculture (CIAT), 2005
[c] WHO Global Health Observatory. Expectation of life at age x, Cambodia. http://apps.who.int/gho/data/?theme=main&vid=60270 (accessed March 8, 2018).
[d] Age-adjusted for age distribution within 15-44 range in FF4F Baseline Survey.

Table 12. Cost-Effectiveness Model for 1000 FF4F Households

Year	Women 15-44 years	CONTROL SCENARIO						EHFP SCENARIO					
		DALYs (Deaths)	DALYs (Stunting)	DALYs (Diarrhea)	DALYs (Pneumonia)	DALYs (Total)	Net Monetary Cost	DALYs (Deaths)	DALYs (Stunting)	DALYs (Diarrhea)	DALYs (Pneumonia)	DALYs (Total)	Net Monetary Cost
Baseline	1107.5												
1	1105.7	9.3	4.2	1.3	1.8	16.7	-$462,210	7.1	3.3	1.0	1.4	12.7	-$381,264
2	1103.9	9.3	4.3	1.4	2.0	16.5	-$448,748	7.1	3.3	1.1	1.5	12.7	-$498,203
3	1102.1	9.2	4.2	1.5	2.0	15.9	-$435,677	7.0	3.2	1.1	1.5	12.2	-$483,692
4	1100.3	8.9	4.2	1.4	2.0	15.2	-$422,988	6.8	3.2	1.1	1.5	11.6	-$469,604
5	1098.4	8.7	4.1	1.4	2.0	14.5	-$410,668	6.7	3.1	1.1	1.5	11.1	-$455,926
6	1096.6	8.5	4.0	1.4	1.9	13.7	-$398,706	6.5	3.1	1.1	1.5	10.5	-$442,647
7	1094.8	8.3	3.9	1.4	1.9	13.0	-$387,094	6.4	3.0	1.1	1.5	10.0	-$429,754
8	1093.0	8.1	3.8	1.3	1.8	12.3	-$375,819	6.2	2.9	1.0	1.4	9.4	-$417,237
9	1091.2	7.9	3.7	1.3	1.8	11.6	-$364,873	6.1	2.9	1.0	1.4	8.9	-$405,085
10	1089.4	7.7	3.6	1.3	1.8	11.0	-$354,245	5.9	2.8	1.0	1.4	8.4	-$393,286
	Total	86.0	40.1	13.8	19.0	**140.3**	**-$4,061,027**	65.9	30.8	10.6	14.6	**107.6**	**-$4,376,698**