Water, Climate Change, and Africa: What Does It Mean?

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Big Picture Thesis

- Thesis: Climate change will alter water access and availability. Coping strategies include ↑ irrigation, water storage, drought resistant crops.
- Most of East Africa's population = farmers
- Eliminating stunting & undernutrition will require provision of adequate and diverse diets; removing environmental contamination; prevention of infectious diseases.
- **Resolution of the above requires water**.

Kenya, 2009 No Water

- Human Needs
- Crop Failures
- Death of cattle

Communities that are resilient in the face of disasters usually have diversified forms of livelihood… and water usually underlies all of them

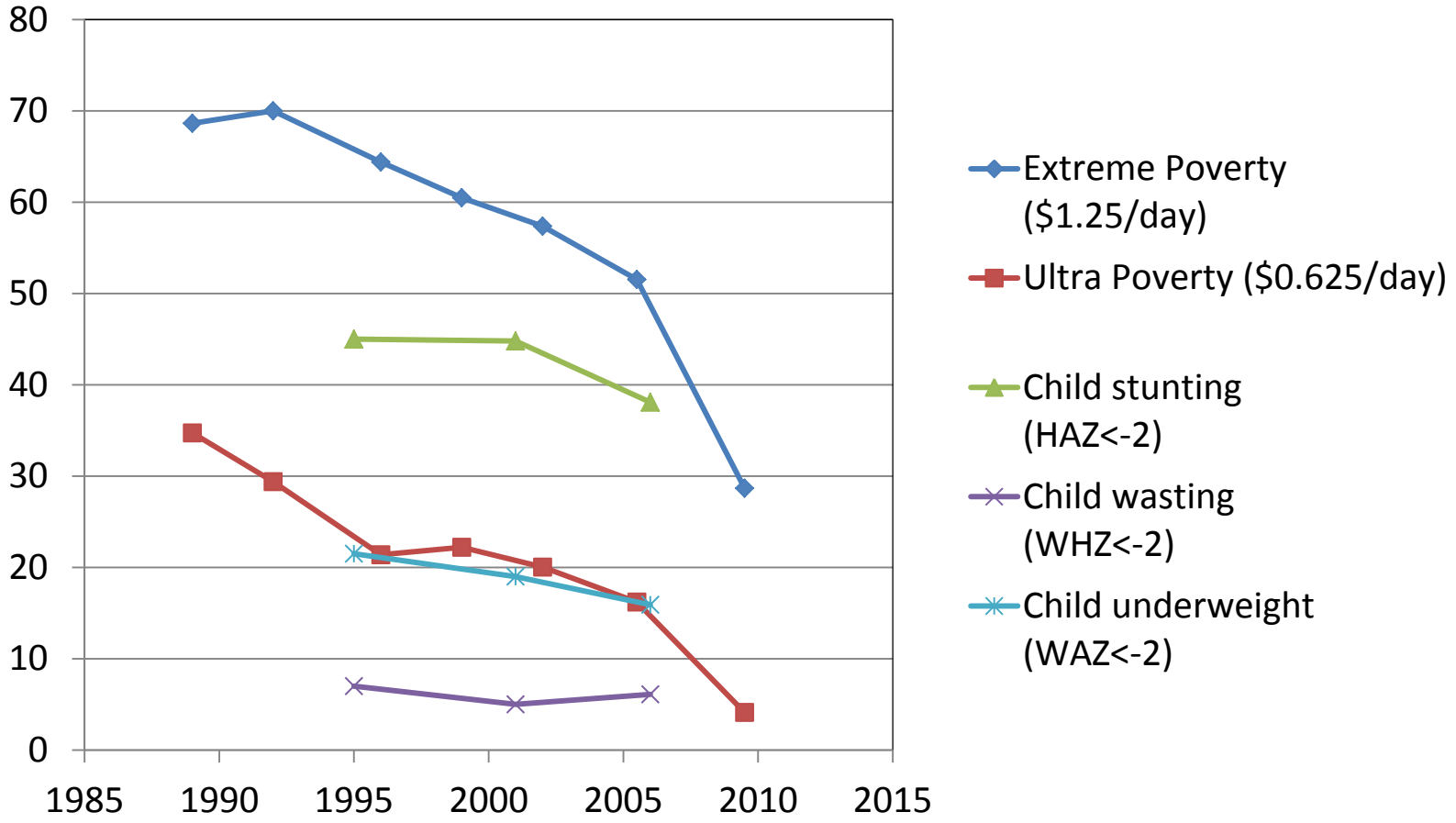
Jehad Nga for the New York Times

Water and Basic Human Needs

Service Level	Access Measure	Needs Met	Health Concern
No access - < 5 L/c/day	> 1 km; 30 minutes	consumption not assured; hygiene not possible	very high
basic - often < 20 L/c/day	100-1000meters; 5-20 minutes	consumption should be assured; hand-washing & basic food hygiene; laundry/bathing no	high
intermediate ~ 50 L/c/day	with 100m, 5 minutes, or by single tap	consumption, ditto basic personal and food hygiene, laundry/bathing	low
optimal > 100 L/c/day	supplied by multiple taps	consumption & hygiene - all needs met	very low
http://www.who.int/water_sanitation_health/diseases/wsh0302/en/			

From presentation by Will Masters: note **steep rate of decline in poverty versus more modest rate of decline in undernutrition** -

Poverty and child undernutrition in Uganda, 1989-2009

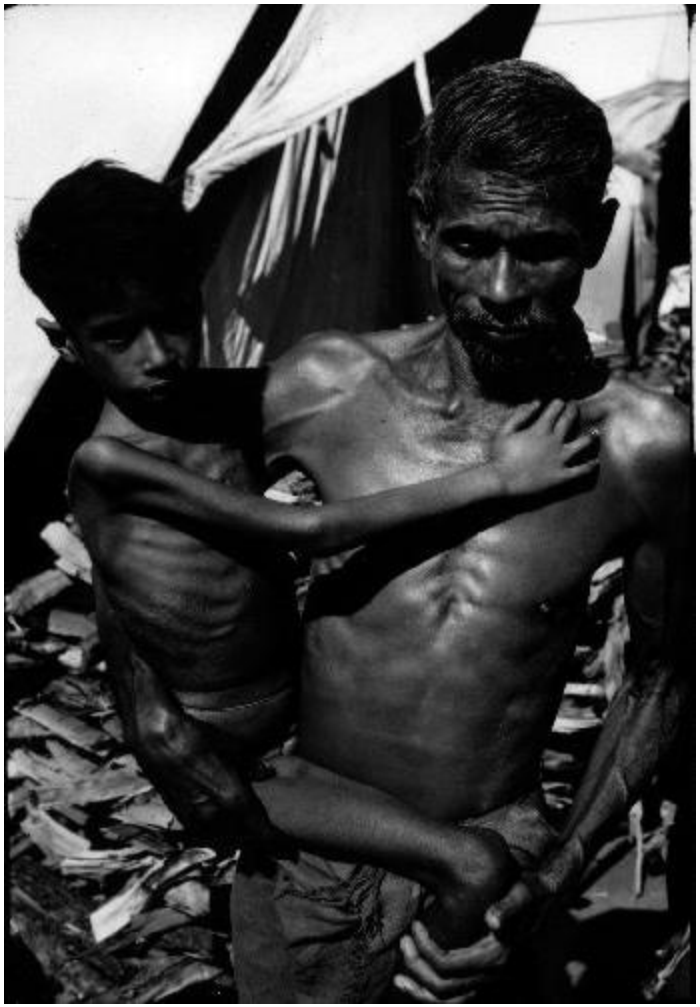


Source: Poverty rates are calculated from World Bank (2011), PovcalNet (http://iresearch.worldbank.org/PovcalNet/), updated 11 April 2011. Estimates are based on over 700 household surveys from more than 120 countries, and refer to per-capita expenditure at purchasing-power parity prices for 2005. Undernutrition rates are from Uganda Demographic and Health Surveys 1995 (Mar.-Aug. 1995), 2000-01 (Sept. 2000-March 2001), and 2006 (May-Oct. 2006).

Stunting – low *height* for age

CDC

Wasting – low *weight* for age

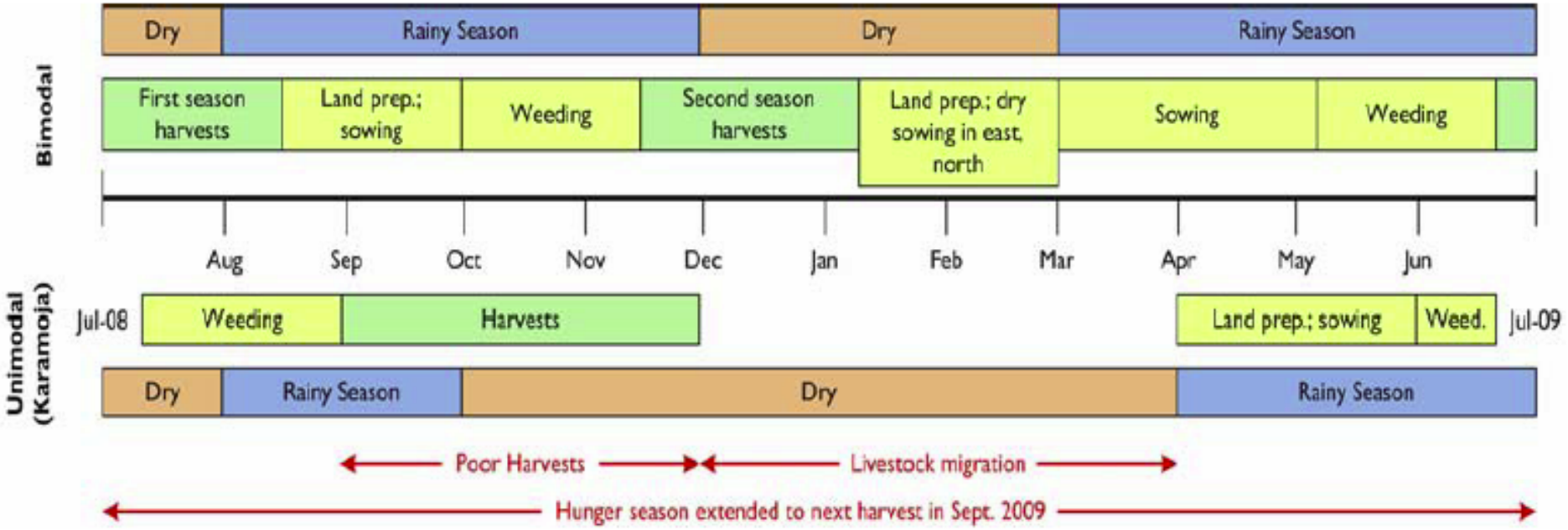


CDC

Background data for Uganda

2 major agro-ecological patterns exist: unimodal north, bimodal south

Figure 25. Seasonal Calendar in Areas With Unimodal or Bimodal Rainy Periods [91]



Water needed for crops, for farm animals (meat protein is good), to keep farmers hydrated and fit for work, …. Irrigation, reservoir construction

What else does the water carry?

AGRICULTURAL WASTEWATER

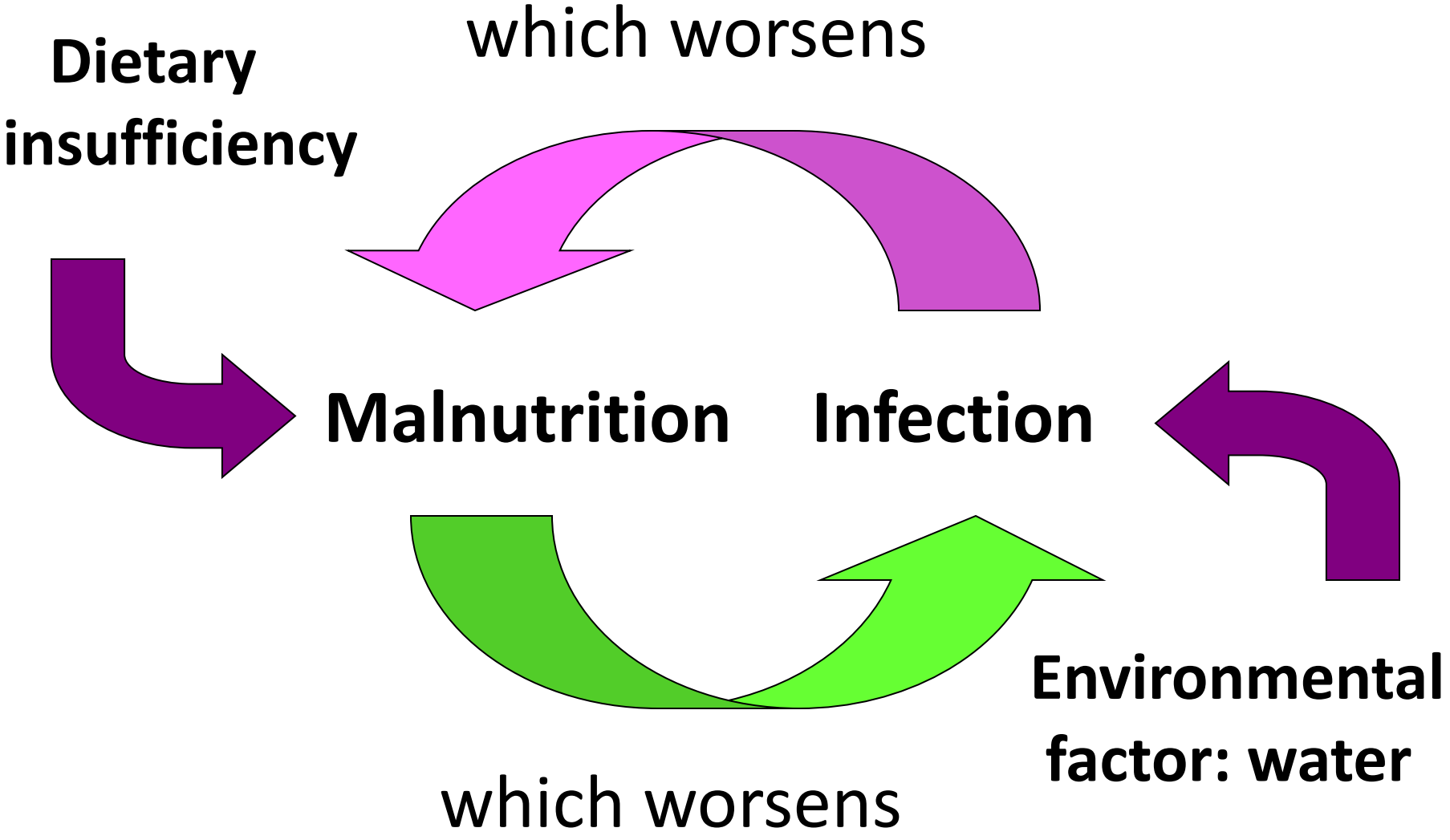
ORGANISM	TYPICAL SOURCE
ROTAVIRUS	HUMANS; PERHAPS ANIMALS
HEPATITIS A	HUMANS
HEPATITIS E	HUMANS, **SWINE**
E. coli (bacteria)	**CATTLE,** HUMANS
Shigella species	HUMANS
Salmonella enterica (bacteria)	**CATTLE, POULTRY, SWINE, HUMANS**
Campylobacter jejuni (bacteria)	**POULTRY**
*Cryptosporidium** (protozoan)	**CATTLE,** HUMANS**, OTHER FARM ANIMALS**
*Microsporidia** (fungus)	**FARM AND DOMESTIC ANIMALS,** HUMANS
* Causes chronic diarrhea, wasting, malnutrition in people with HIV/AIDS	
Cryptosporidium – a leading cause of diarrhea children < 24 months; known to cause stunting; and children have x 4 risk of death in next year	

Pathogens in Rural and Agricultural Water and Watersheds. USDA 2010

Agriculture in Urban Nairobi: Sewage

Left: broken sewage main in field. Right: lush fields.

Farmers work in contaminated fields; crops contaminated with human pathogens; go home to families carrying tools & wearing boots that have been in sewage…


which worsens
Dietary insufficiency
Malnutrition
Infection
Environmental factor: water
which worsens

High potential for domestic animals and people to contaminate household environment

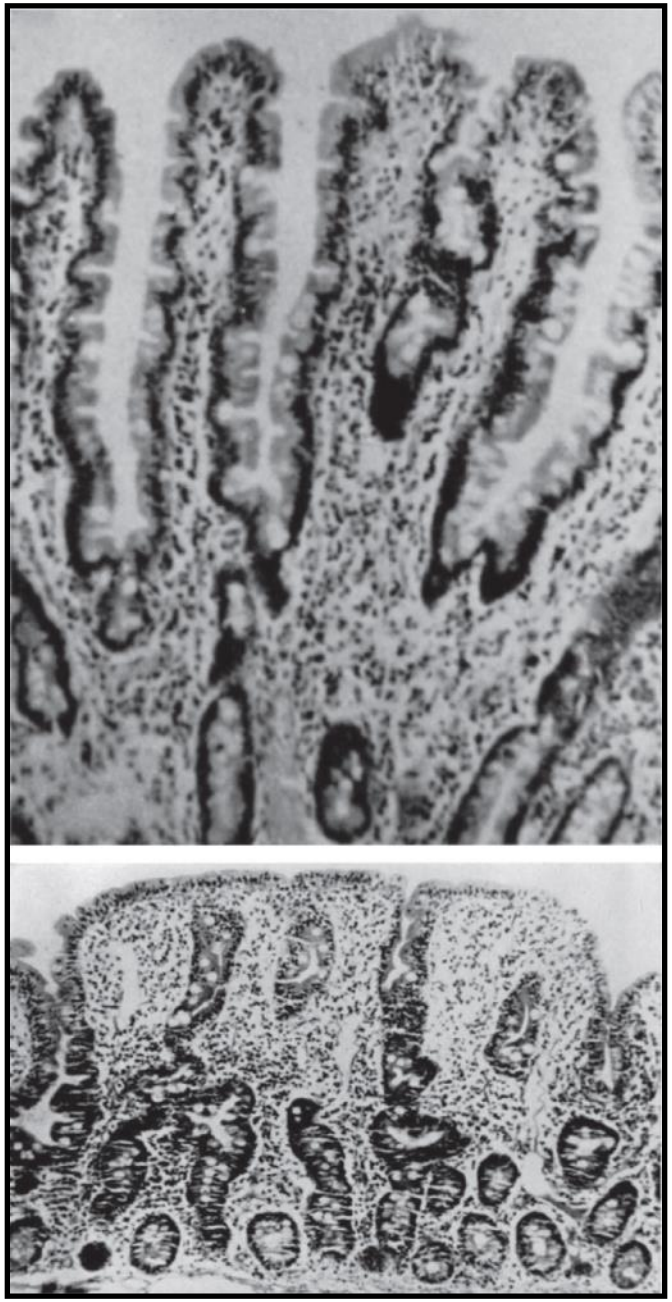
Poor Sanitation / Hygiene. Fecal Contamination of Domestic Environment

Fecal Ingestion Infants/Children and Enteric Infections

(1) Intestinal Inflammation (2) Increased gut permeability (3) Bacteria get into body via leaky gut (4) **Entire Immune System gets activated**

ENVIRONMENTAL ENTEROPATHY

Malabsorption & Malnutrition; Oral Vaccine Failure; ↑ Risk of Infection; ↑ Morbidity/Mortality, ↓ Cognition, Economic Potential



ENVIRONMENTAL ENTEROPATHY (EE)

People living in contaminated environments have leaky, chronically inflamed intestines

EE - Short blunted villi, tissue is infiltrated with inflammatory cells. 15% less protein and 5% less carbohydrate is absorbed. ↑ nutritional needs, bacteria leak into body, leads to anemia. **Bad bacteria** are likely cause.

Korpe & Petri, Trends in Molecular Medicine June 2012, Vol. 18, No. 6

INSIDE YOUR GUT

Microbiome modulates your immune system

Diverse Microbiome

Microbiome of 1000-1150 species produces amino acids, short-chain fatty acids, and others which feed intestinal cells and shift your metabolic stance

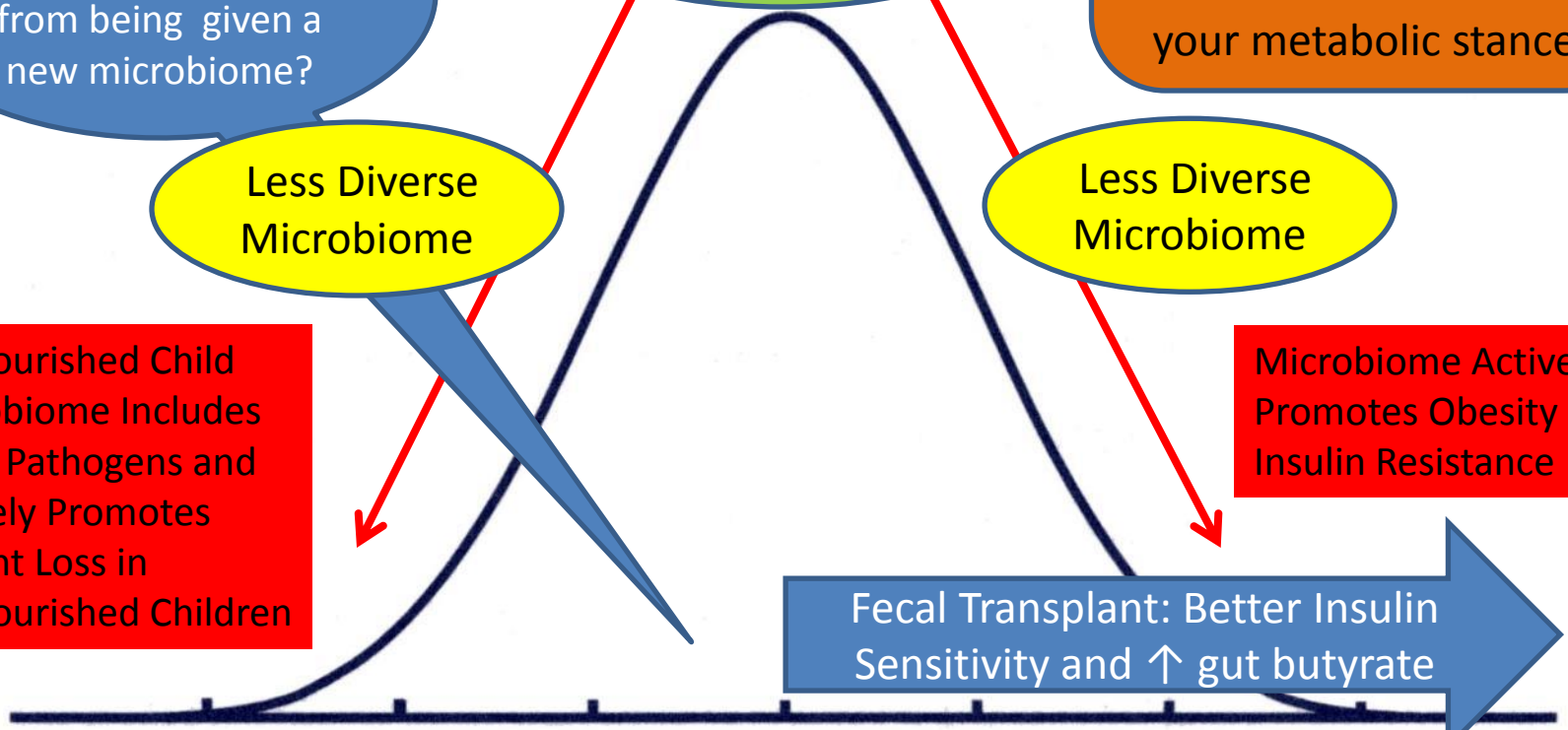
Could malnourished children benefit from being given a new microbiome?

Less Diverse Microbiome

Less Diverse Microbiome

Malnourished Child Microbiome Includes More Pathogens and Actively Promotes Weight Loss in Malnourished Children

Microbiome Actively Promotes Obesity and Insulin Resistance



Gut Microbiomes of Malawian Twin Pairs Discordant for Kwashiorkor

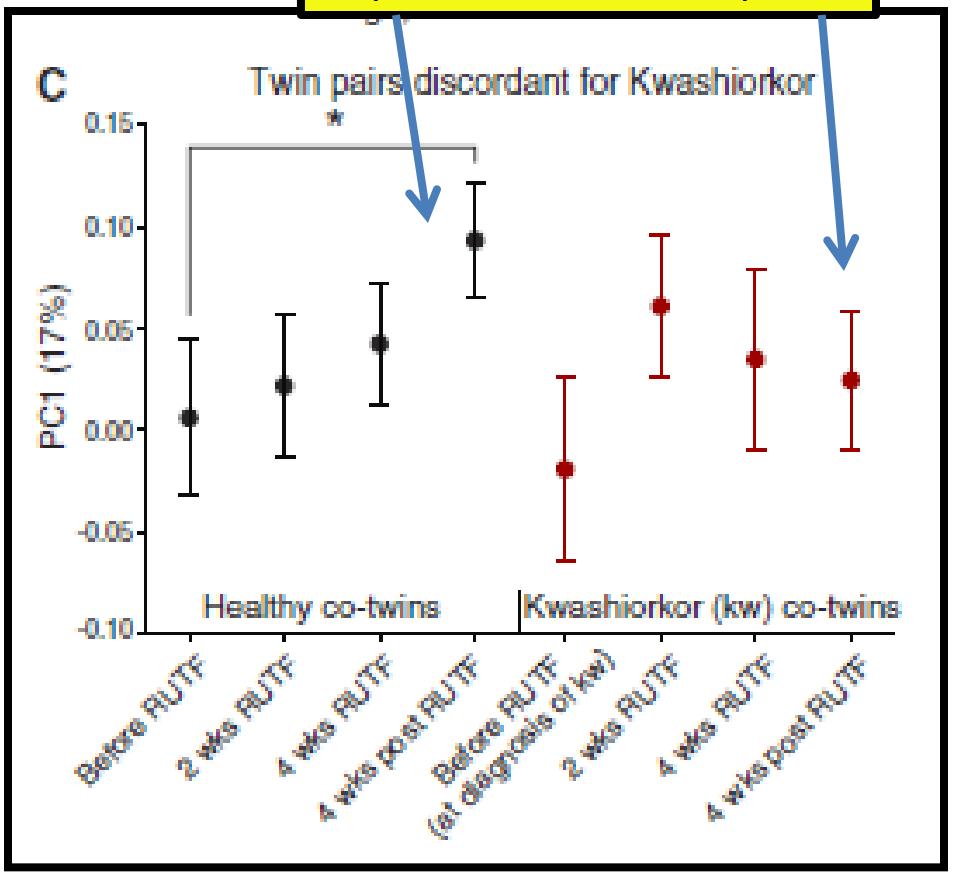
Michelle I. Smith,[1*] Tanya Yatsunenko,[1*] Mark J. Manary,[2,3,4] Indi Trehan,[2,3] Rajhab Mkakosya,[5] Jiye Cheng,[1] Andrew L. Kau,[1] Stephen S. Rich,[6] Patrick Concannon,[6] Josyf C. Mychaleckyj,[6] Jie Liu,[7] Eric Houpt,[7] Jia V. Li,[8] Elaine Holmes,[8] Jeremy Nicholson,[8] Dan Knights,[9,10]† Luke K. Ursell,[11] Rob Knight,[9,10,11,12] Jeffrey I. Gordon[1]‡

Science 339:548-554.

1 February 2013

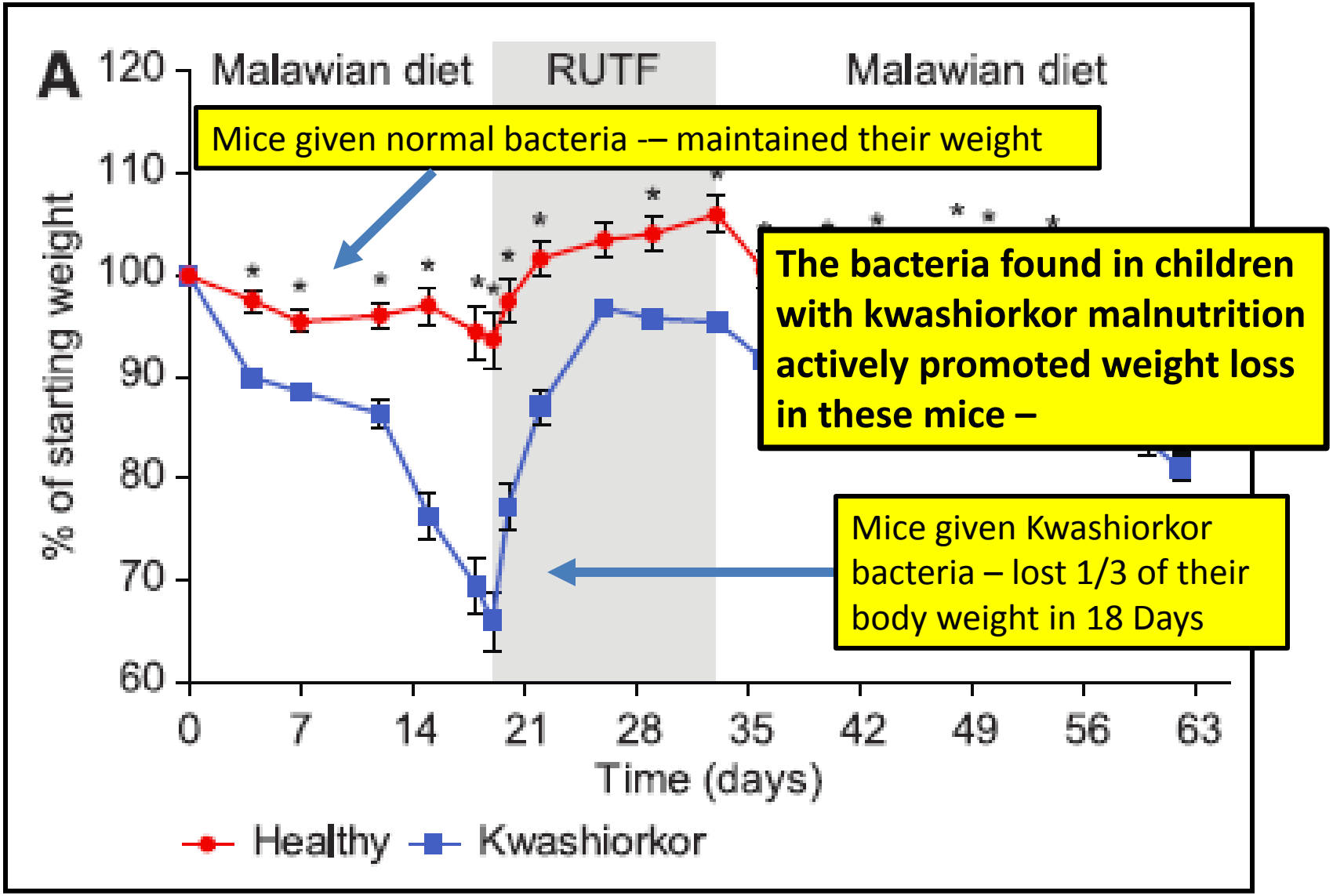
- 317 Malawian twins studied first 3 years of life
- 50% both well nourished; 43% <u>discordant</u> (one well, one malnourished); 7% both were malnourished.
- <u>Both</u> twins in discordant pairs received RUTF, a therapeutic food. Gut microbiomes (MB) studied: RUTF → transient MB improvement.

Improve Don't Improve



Then…

Gnotobiotic (sterile gut) mice – given Normal or Kwashiorkor Microbiomes from Malawian Children



Microbiota: energy metabolism

sible for converting succinate to fumarate. Taken together, these observations suggest that the kwashiorkor microbiota examined in these gnotobiotic mice may generate chemical products that result in a selective inhibition of one or more TCA cycle enzymes, making energy metabolism a bigger challenge for these children when they are exposed to a micro- and macronutrient-deficient, low-calorie diet.

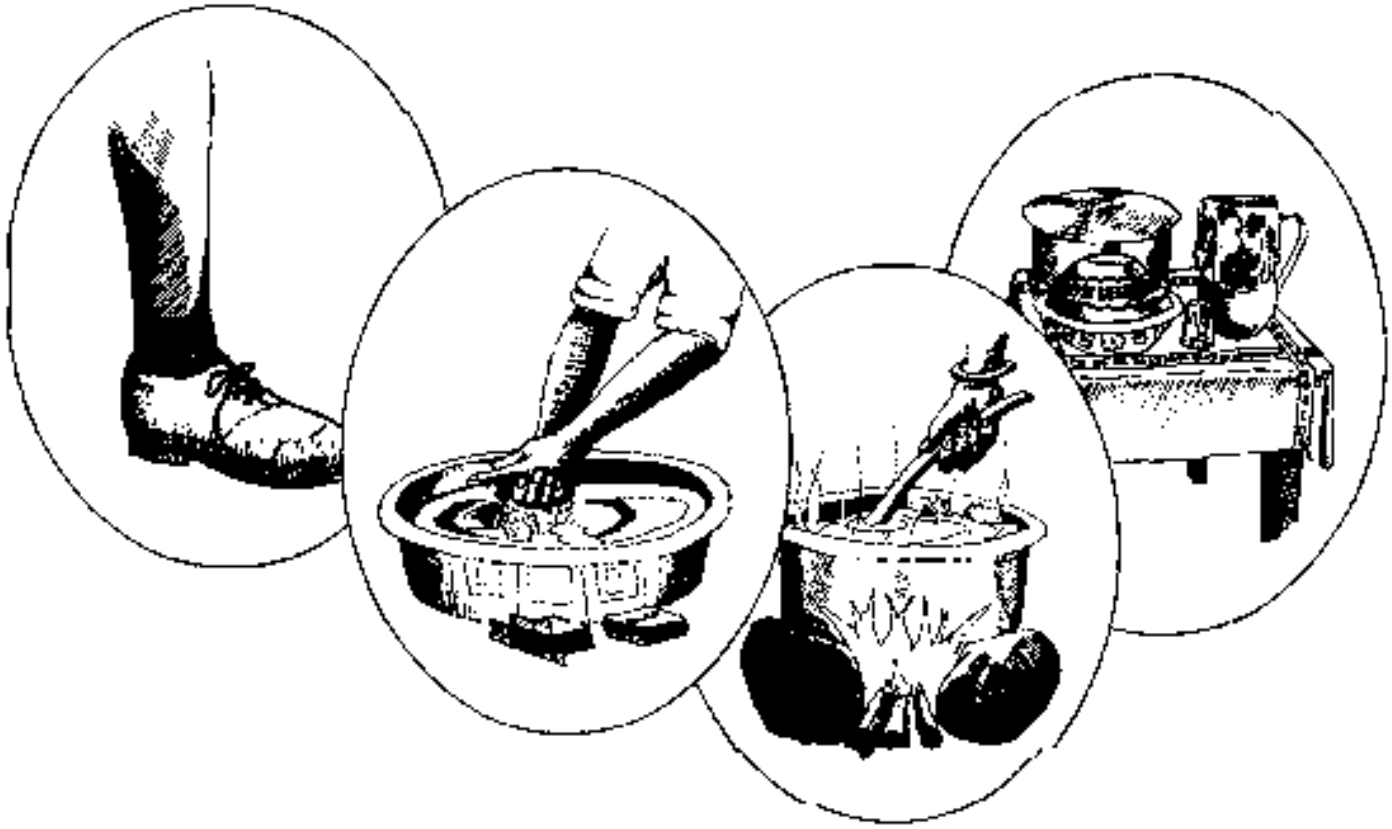
The kwashiorkor microbiome bacteria generate chemicals which inhibit key energy metabolism

Solutions

- **Classic household water & sanitation** – water supply NOT same for animals unless treated; hand-washing; human and animal feces kept out of wastewater to increase food safety.
- **Agricultural hygiene** – barriers to keep feces and crud out of water - vegetated buffer zones around crops, riparian buffers to slow entry into open water (stream or irrigation canal), manure management, grazing practices …

January 4 2013: FDA proposes rules to “ensure water used in irrigation meets standards…”

Farm practices to control spread of disease are well known



PHAST Step-by-Step Guide: A Participatory Approach for the Control of Diarrhoeal Disease (SIDA - UNDP - WB - WHO, 1998, 124 p.)

Back to first principles

So far, this talk has focused on water and agriculture, health, and nutrition. A key concept is keeping fecal material – be it human or animal – out of food and the environment. Water is critical to this separation.

- What independent **evidence** supports the benefits cited?
- Dean Spears has looked at open defecation as a marker of sanitation using 140 DHS data sets from 60 countries.

How much international variation in child height can sanitation explain?

Dean Spears*

First circulated: 10 December 2012
This version: 17 January 2013

Key findings Spear's analysis of 140 DHS from 65 'developing' countries

- Open defecation (certainly a marker of a "contaminated environment") is linked to a **1.24 S.D. decrease** in the height of children.
- **Sanitation alone** accounts for **54%** of the between-country height variation (next slide).
- Open defecation and a lack of sanitation in an household, along with country GDP, predict child height *more than* mother's height or education; governance; or infrastructure.

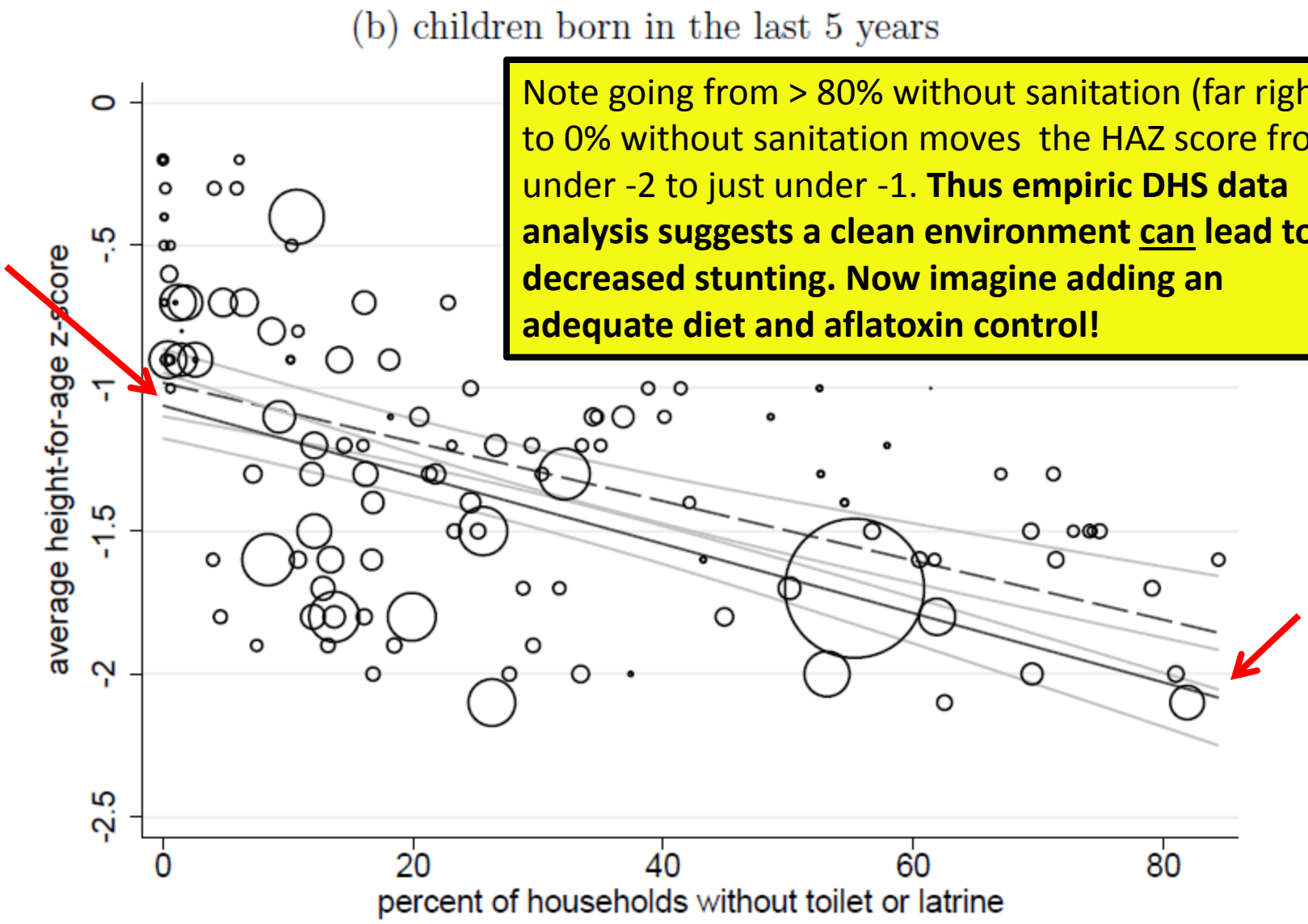


Figure 1: Open defecation predicts child height, across DHS survey round country-years

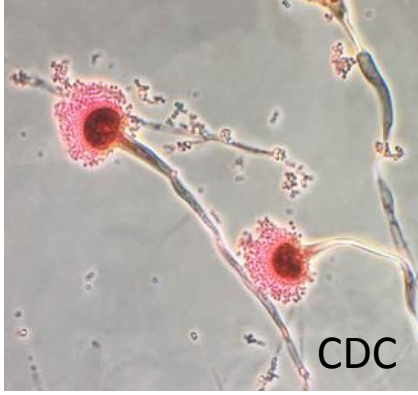
Solid OLS regression lines weight by country population; dashed lines are unweighted.

Aflatoxins and other mycotoxins

Drying Cassava Dec 8th 2012, Kamwenge: note green/yellow fungal discoloration

Photo: J K Griffiths Uganda December 2012

Aflatoxins (aflatoxins are a subset of mycotoxins)

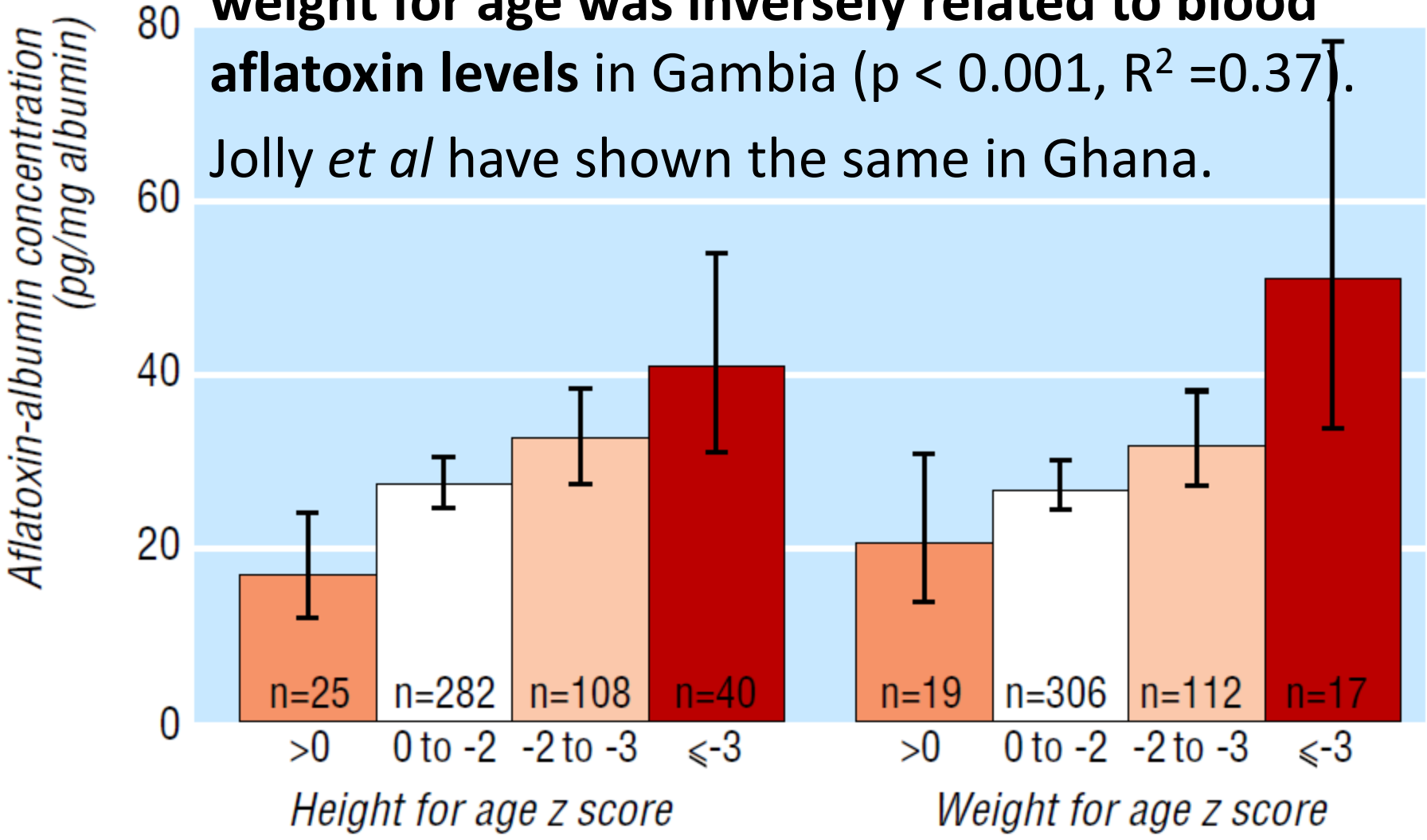


- Produced by *Aspergillus* fungus
- Known – hepatoxic & cause liver cancer in people
- Known in mammals to cause growth faltering and ↓ *in utero* growth (e.g. low birth weight)
- Associated* with lower birth weight, growth, stunting, and wasting in children
- Associated* with lower CD4 and higher viral loads (e.g. worse immunity) in people with HIV
- Widespread exposure in sub-Saharan Africa, SE Asia; maize, peanuts, many other crops.

*Some criticize these studies for only being "associative" - but it is *unethical* to give aflatoxins to people. Prospective studies of exposure and outcomes are needed to show "causation."

Gong et al (BMJ, 2002) showed that **stunting** and **weight for age was inversely related to blood aflatoxin levels** in Gambia ($p < 0.001$, $R^2 = 0.37$).

Jolly *et al* have shown the same in Ghana.



Aflatoxins II

- Contamination occurs in the field; promoted by poor post-harvest storage.
- Passed *in utero* and in breast milk to children
- Complementary food (e.g. porridge made from maize) is frequently contaminated – as are milk, eggs, chickens, animal meats…
- Prevention: storage without moisture/oxygen; dispersal of natural variant *Aspergillus* which lacks toxin; test and condemn crops/foods
- Needed: markets for aflatoxin-free foods!

P. Turner et al showed (Lancet 2005) these 5 methods reduced blood aflatoxins by 60%:

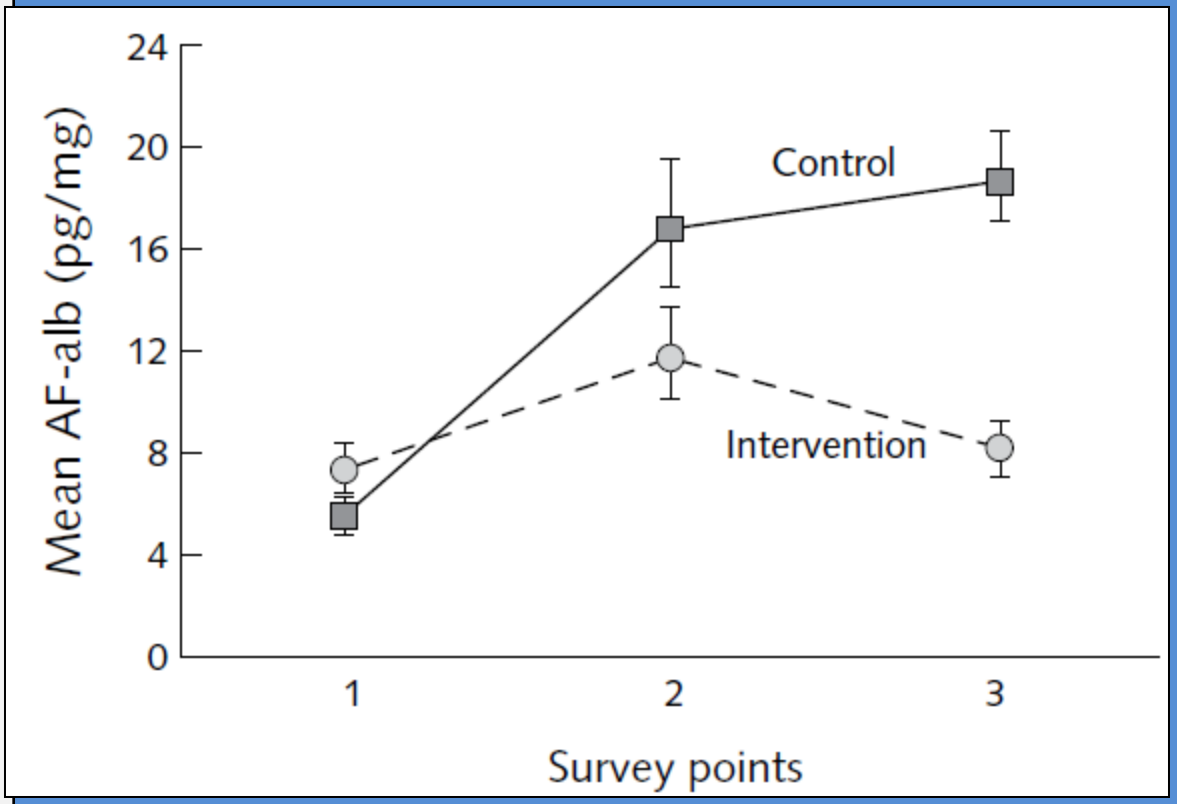
1. Sun dry thoroughly on mats, not ground;

2. hand sort and discard moldy nuts;

3. use fiber (not plastic) sacks for storage;

4. store storage sacks on pallets, above the ground;

5. spray insecticide on ground under the pallets to reduce insect damage.



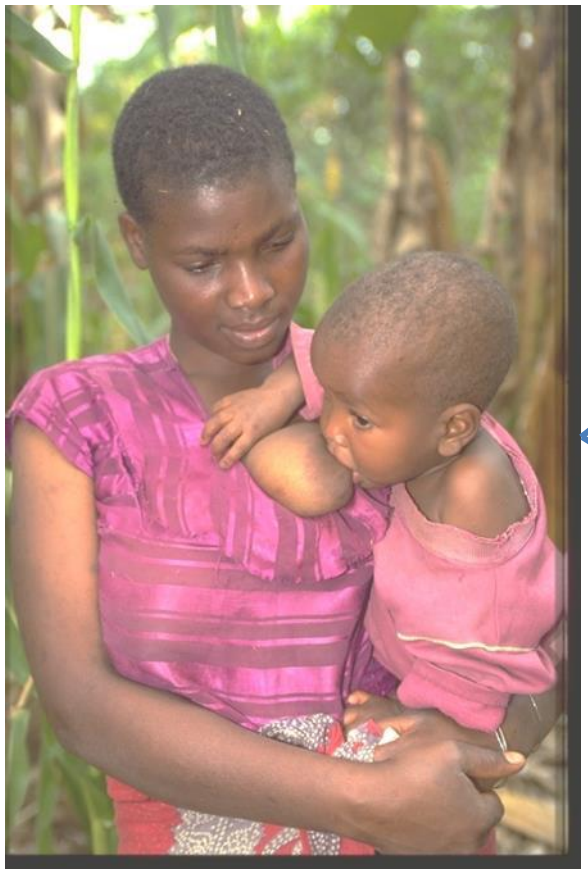
Post-Harvest Handling Can Decrease Aflatoxins in Those Who Eat the Groundnuts

CONTAMINATED WATER / POOR HYGIENE
(PATHOGENS, OTHER STUFF IN WATER)

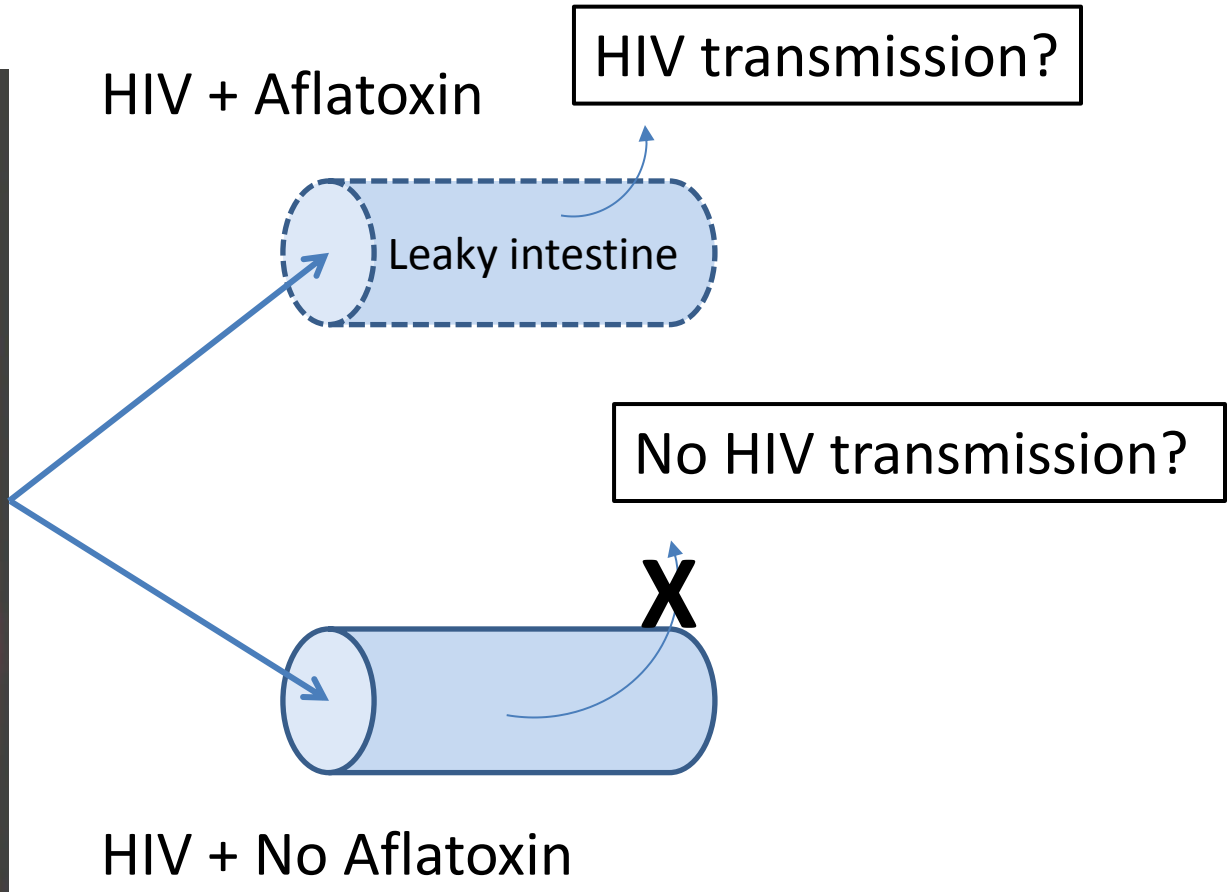
ENVIRONMENTAL ENTEROPATHY & STUNTING

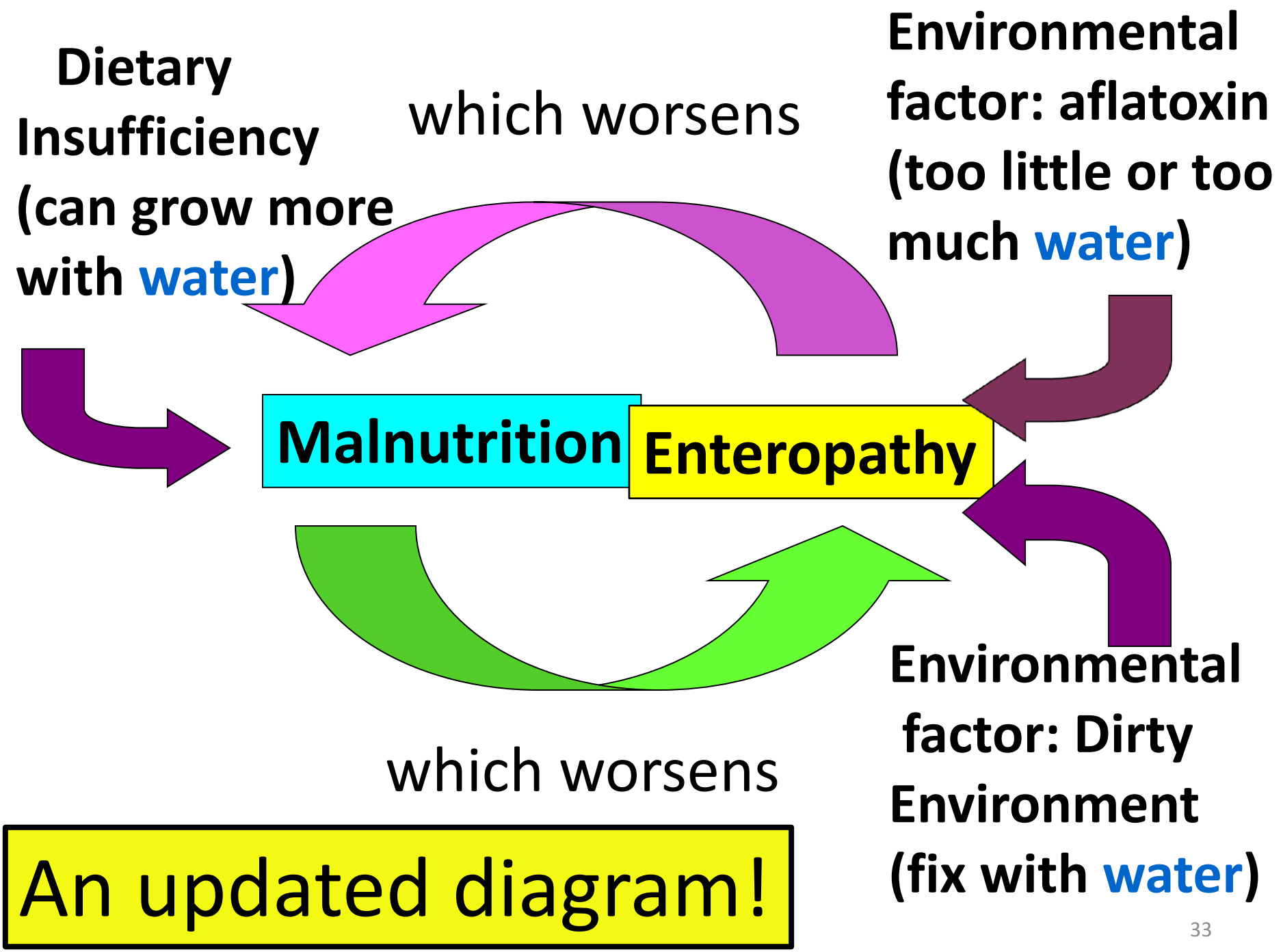
AFLATOXIN (MYCOTOXIN) INGESTION
(FUNGI NEED WATER/MOISTURE TO GROW)

Aflatoxin is in breast milk – could this have an impact on disease transmission? No one knows.



hivthisweek.unaids.org





An updated diagram!

Agricultural Water Projects

- Rational response to climate change
- Increase food production
- Increase burden of diseases related to water, including malaria and schistosomiasis. Long history of failure to consider health risks. Can undermine the benefits of bednet use and intermittent treatment of malaria during pregnancy
- Increase in commerce can lead to ↑ HIV risk
- Thoughtful water system management should act to mitigate risks while maximizing benefits

Example - Malaria:

"The construction of irrigation systems and reservoirs in some parts of the world can have a dramatic impact on malaria distribution and on the intensity of its transmission…. Malaria is among the five leading causes of death in under-5-year-old children in Africa."

"Where appropriate, countries and communities are being encouraged to reduce mosquito breeding sites by filling in and draining water bodies and through other environmental management schemes."

WHO http://www.who.int/water_sanitation_health/diseases/malaria/en/

KOKA RESERVOIR

CATTLE – (DEFECATE IN WATER)

WONJI IRRIGATION AREA

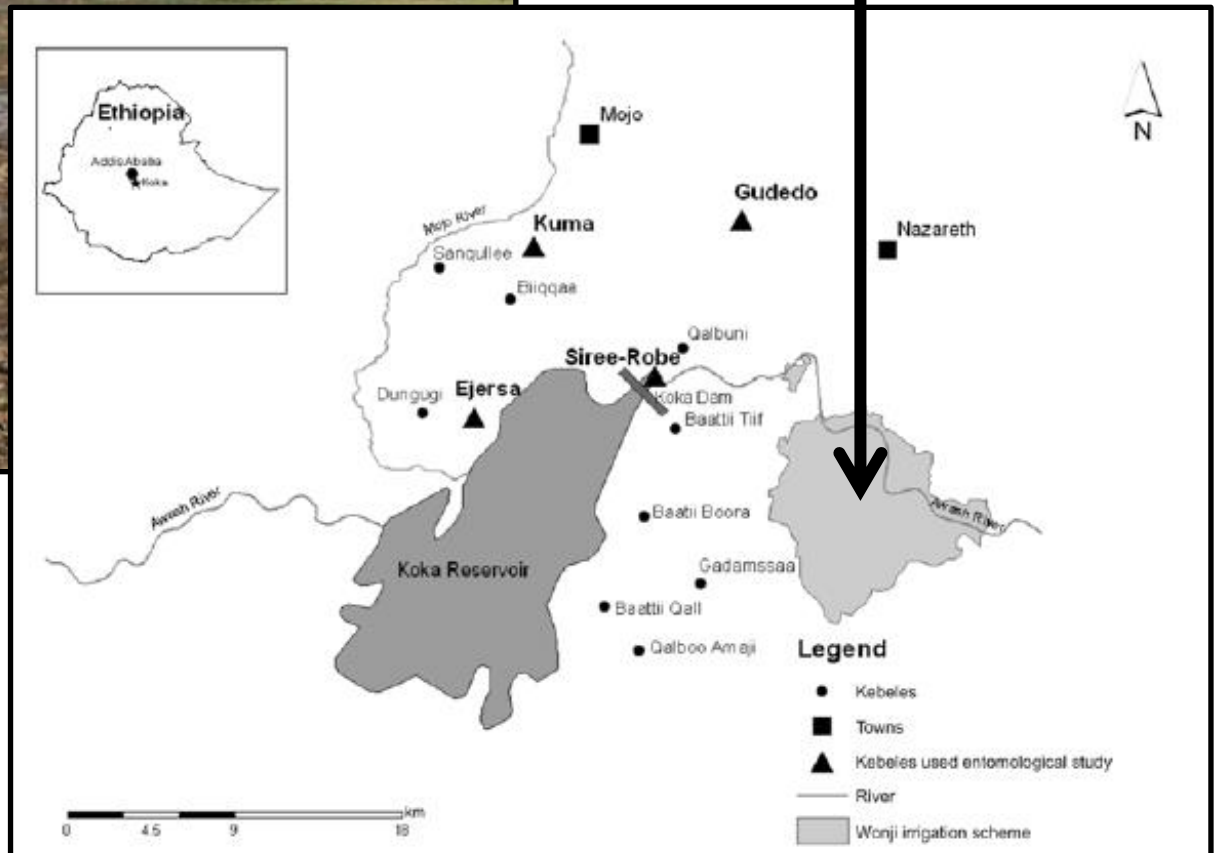


FIGURE 2. Location of the Koka area in central Ethiopia. The triangular points represent each of the study villages.

Closer to reservoir, more malaria

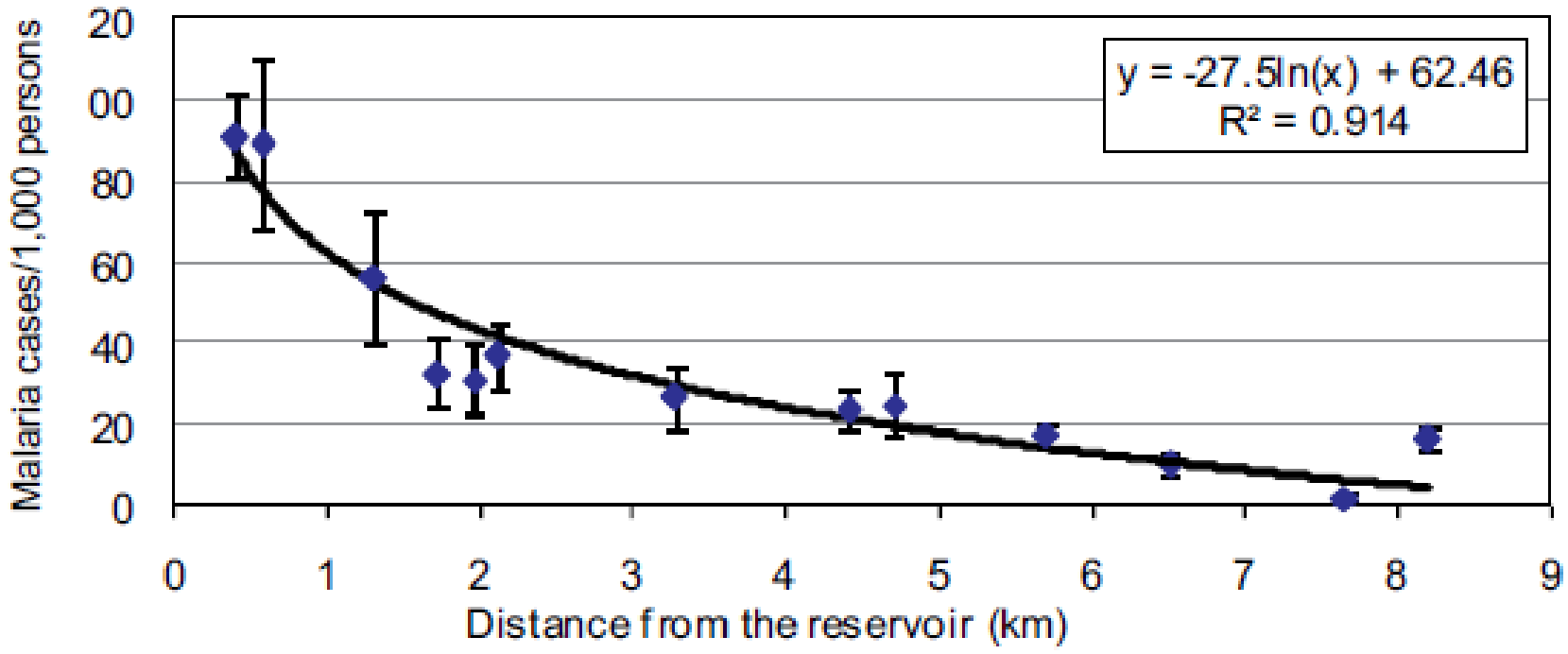


FIGURE 8. Relationship between average annual malaria case rates in 13 villages (passively reported) and proximity to the Koka Reservoir between 1995 and 2007. The bars indicate the confidence interval of the observed means.

… more malaria, even “out of season”

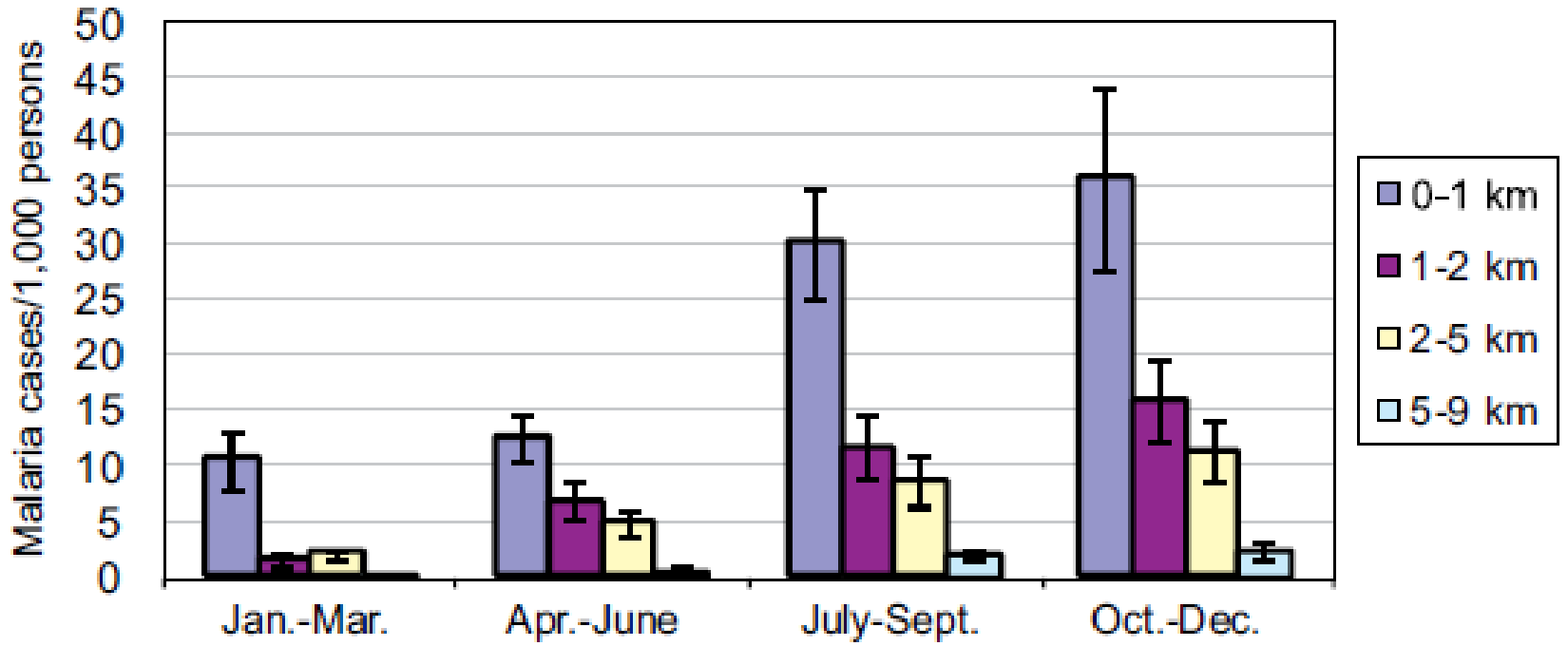
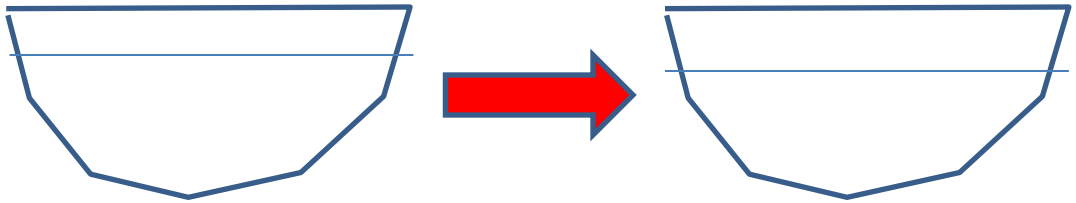
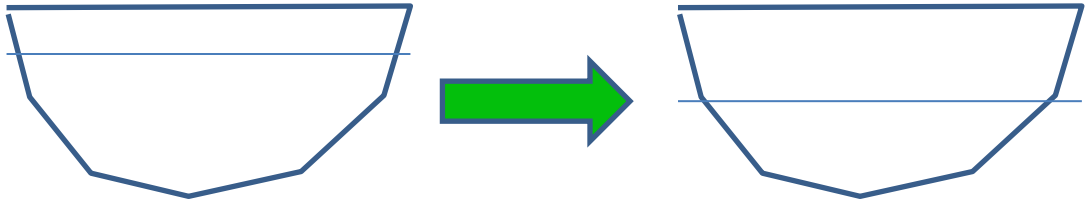


FIGURE 9. Seasonal distribution of malaria cases passively reported at different distances from the Koka Reservoir (vertical bars indicate 95% confidence intervals).

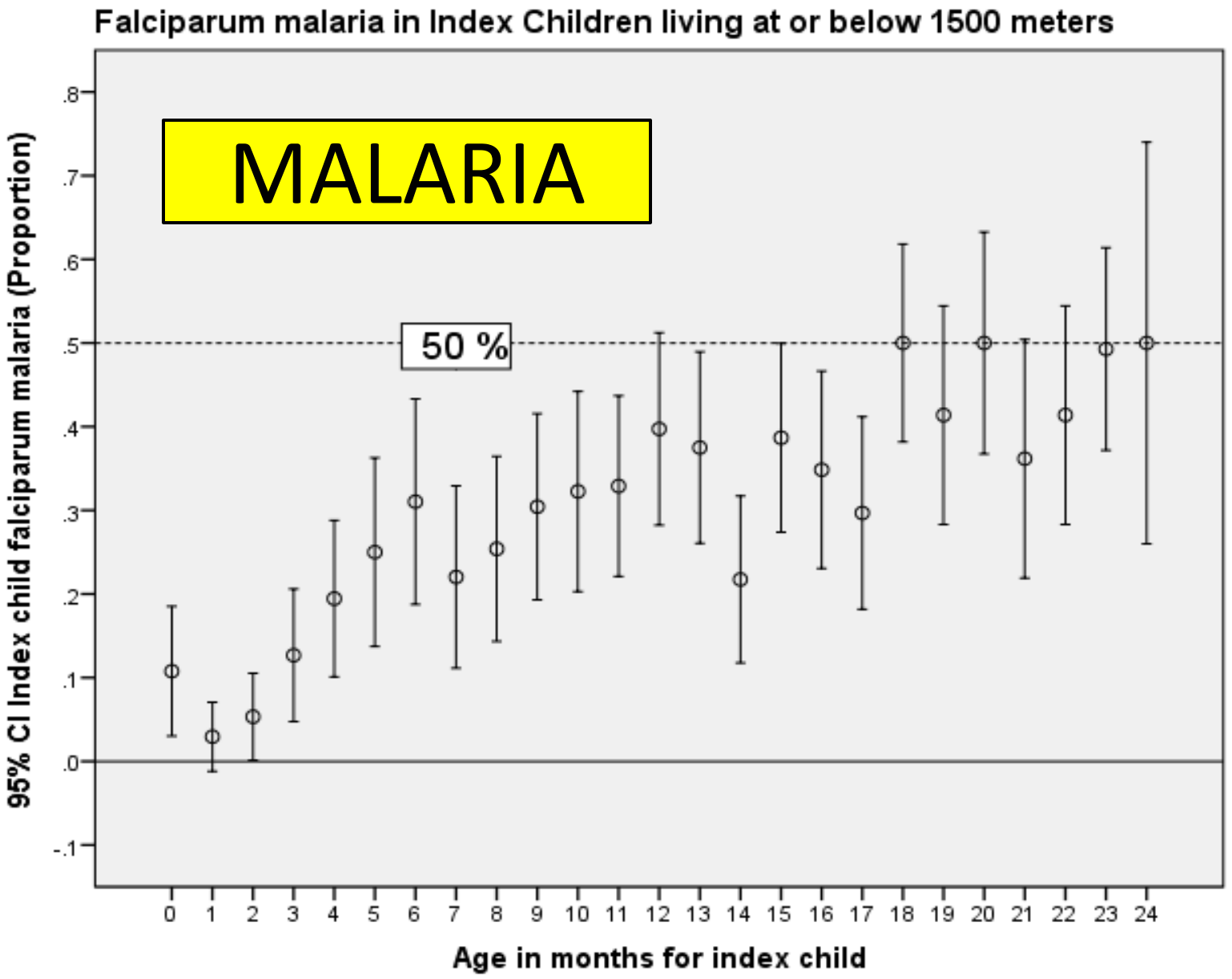
Control: Leave larvae high & dry



SLOW DRAWDOWN OF WATER – MOSQUITO LARVAE SURVIVE



ABRUPT DRAWDOWN OF WATER – MOSQUITO LARVAE LEFT HIGH & DRY DO NOT SURVIVE



Griffiths et al 2013. 2012 Survey Results. Makerere University, Kampala, Uganda June

Summary:

- Climate change will, over time, drive food production and livelihoods in much of Africa
- Providing food to undernourished people only solves some of the malnutrition problem. Recent science: contaminated environments, infections, and toxins adversely change the gut. Resolving these issues requires water.
- Water & Sanitation have much more potential to eliminate malnutrition than had been thought.

Thanks!

Questions: jeffrey.griffiths @ tufts.edu

Photo: JK Griffiths Tanzania 2008 Harvard talk August 8, 2013