FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

Effective pathways towards reducing chronic malnutrition

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Symposium: Ensuring children's cognitive and physical development through animal-source foods

Capitol Hill Club, June 5, 2019

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ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

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Presentation Outline

1. Introduction
- The problem: stunting
- Biological and evolutionary basis of ASF

2. Evidence
- Ecuador: Lulun Project
- Kenya: Samburu, coastal areas

3. Conclusion
- ASF for achieving global milestones
- Key messages

Malnutrition: prevalence

Malnutrition in young children

151 million *stunted growth; 250* million *stunted development*

50 million *wasted*

41 million *overweight/obese*

Hidden hunger globally

33% children *vitamin A* deficient

18% children & 19% women anemic

17.3% world *zinc* deficient;

28% world *iodine* deficient

3.1 million (45%) of deaths to children <5 yr

(Black et al. *Lancet* 2013)

Periods of greatest risk for chronic malnutrition

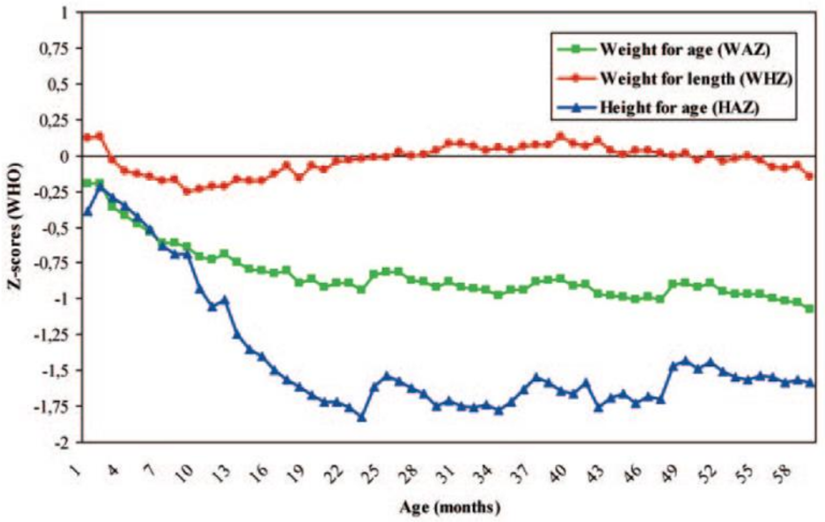
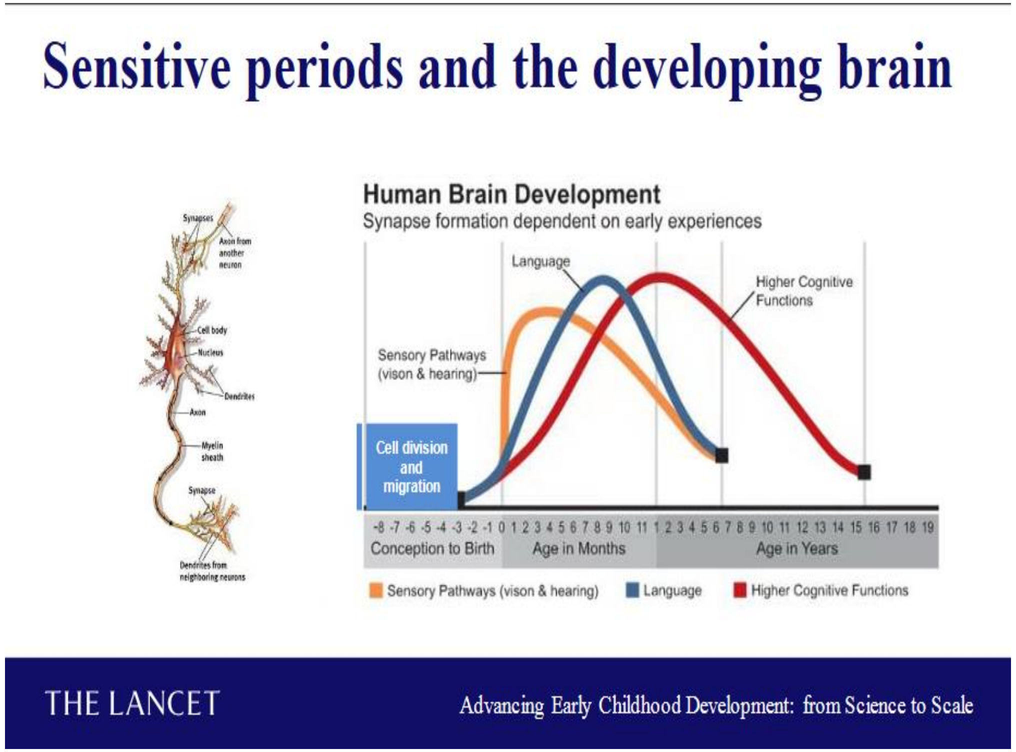


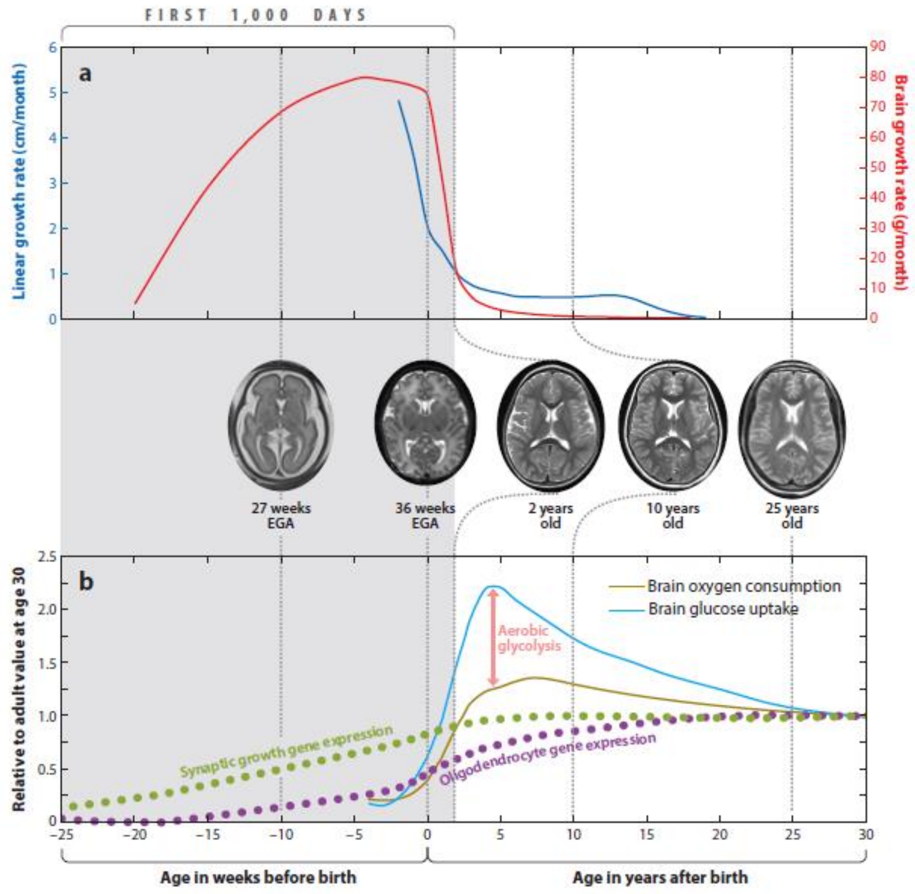
FIGURE 1
Mean anthropometric *z* scores according to age for all 54 studies, relative to the WHO standard (1 to 59 months).

(Victora et al., Pediatrics 2010)



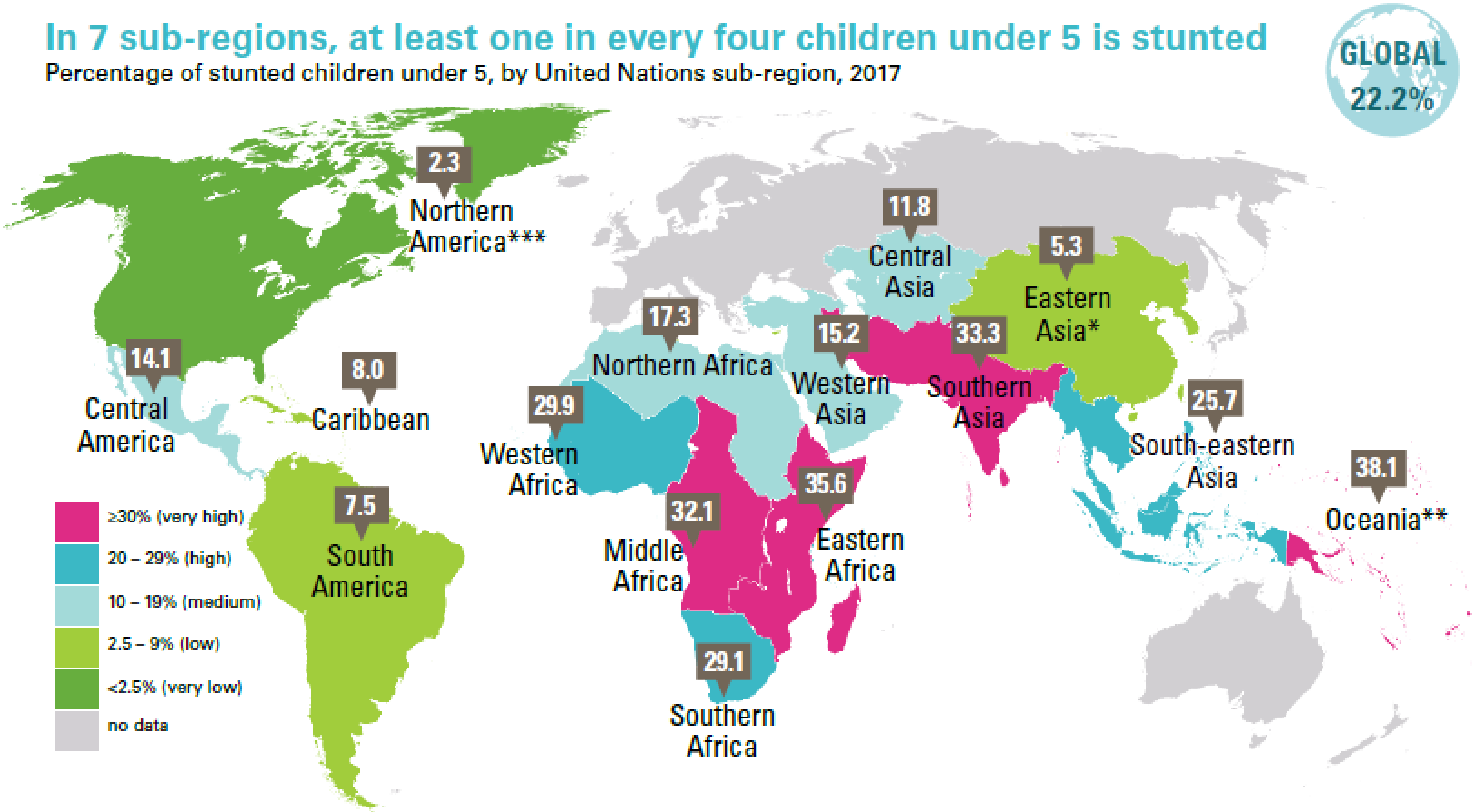
Hidden hunger & brain development

- "Brain-selective" nutrients
  - Iodine (thyroid hormone), iron (white matter, myelination, neurotransmitter metabolism), zinc (enzymes, neurotransmitter), copper, selenium, DHA , choline, vitamins A and B12
  - Deficiencies → hippocampus insults, ↓ learning and memory, compromised child development across all domains, etc.



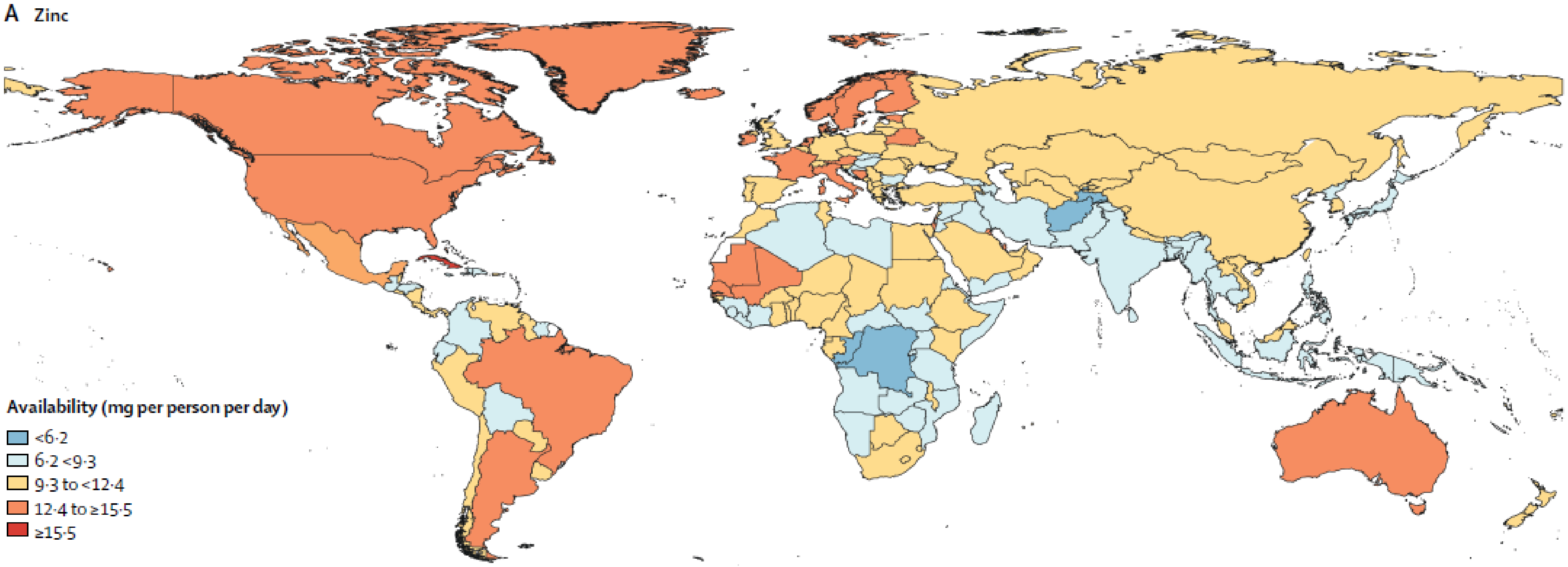
Goyal, Iannotti and Raichle *Annual Review of Nutrition* 2018

Global Stunting

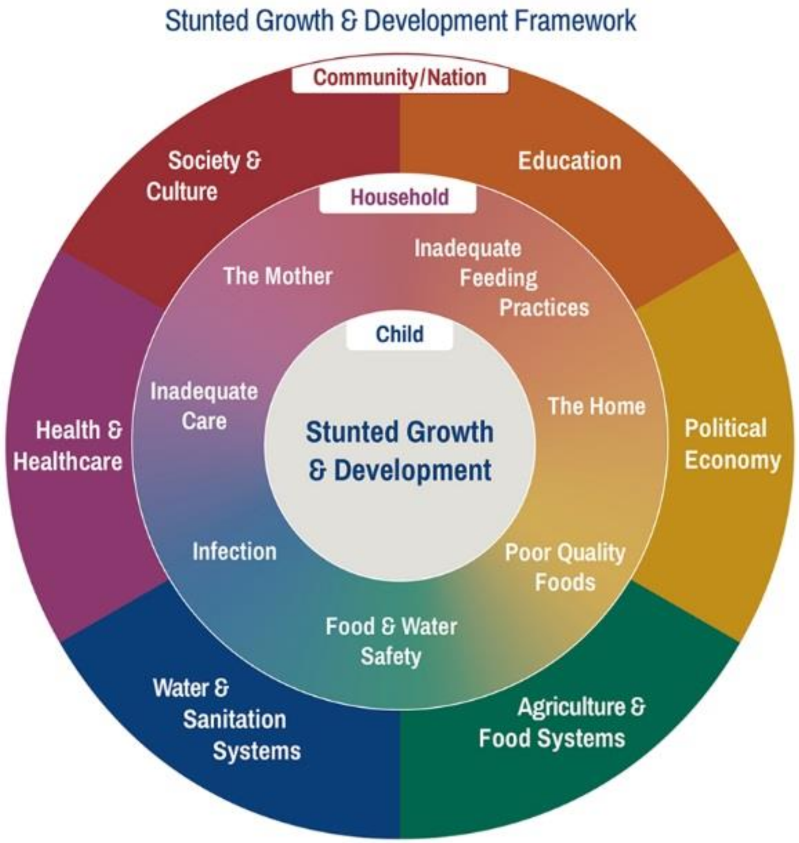


UNICEF WHO World Bank 2018

Nutrient disparities: zinc availability (*Lancet* Planetary Health series 2018)



Stunting: Causes & Consequences



WHO 2014

Consequences:

- ↑ risk of mortality
- ↑ risk of infectious diseases (enteric, malaria, respiratory)
- Impaired development
- ↓ schooling
- ↓ adult earnings
- Poor reproductive health
- Intergenerational effects

Evolutionary Nutrition: Theories

- Discordance theory
  - Human genome evolved to adapt to conditions that no longer exist. Mismatch leading to ↑ chronic diseases (Eaton & Konner NEJM 1985)
  - Genome-nutrition divergence of divergence across the entire nutrition spectrum, with overlapping region of poor diet quality (Eaton & Iannotti Nutrition Reviews 2017)

- Shore-based paradigm
  - Archeological evidence (e.g. shell middens) points to emergence of *Homo sapiens* and anthropometric differences in body and brain, driven by shore-based diets (Cunnane & Crawford 2014)

- Savanna & Woodland theories
  - Hominin as hunter on savanna & woodland → grassy woodland (Washburn & Lancaster 1968; Stanford et al. 1999; White et al. 2009)

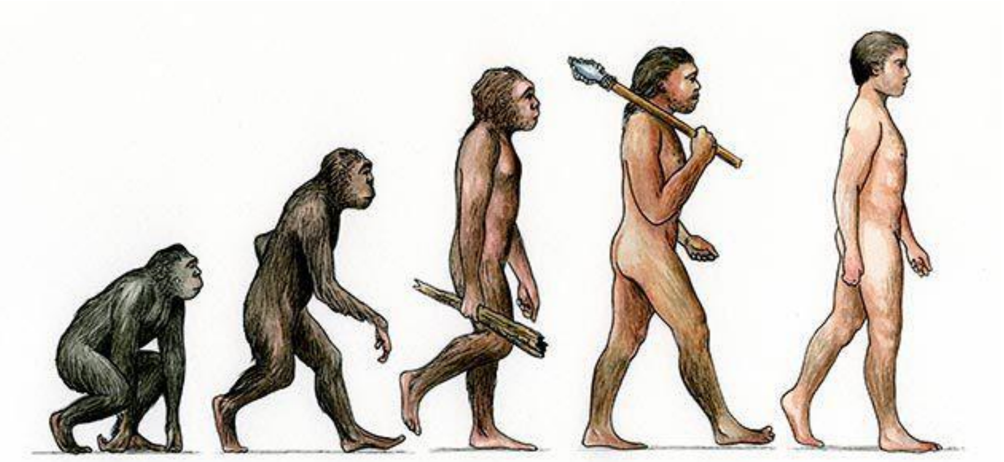
https://www.allaboutbirds.org/guide/Common_Gallinule/id

The *Homo* genus: anatomical differences

- *Homo erectus* (early hominin) ~1.8 mya
  - Anatomical differences from other *hominins* (*Australopithecus garhi* & *Homo habilis*), attributable to diet changes - animal source foods in particular.

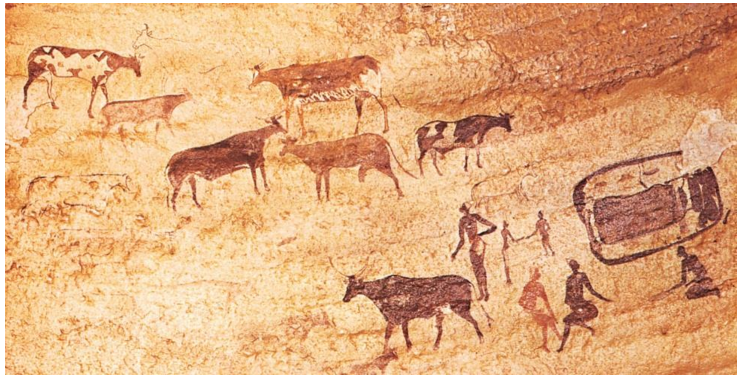
<u>Physical Differences</u>

- ↑ Brain size – 3x the encephalization quotient (brain mass to body mass) (Broadhurst et al. 1998)
- ↑ Taller height - 15% taller (Walker 1993)
- ↑ Larger body mass
- ↑ Longer legs (bipedalism)
- ↓ Smaller teeth
- ↓ Colon, ↑ small intestine (>56%)



https://www.smithsonianmag.com/science-nature/the-top-ten-daily-consequences-of-having-evolved-72743121/

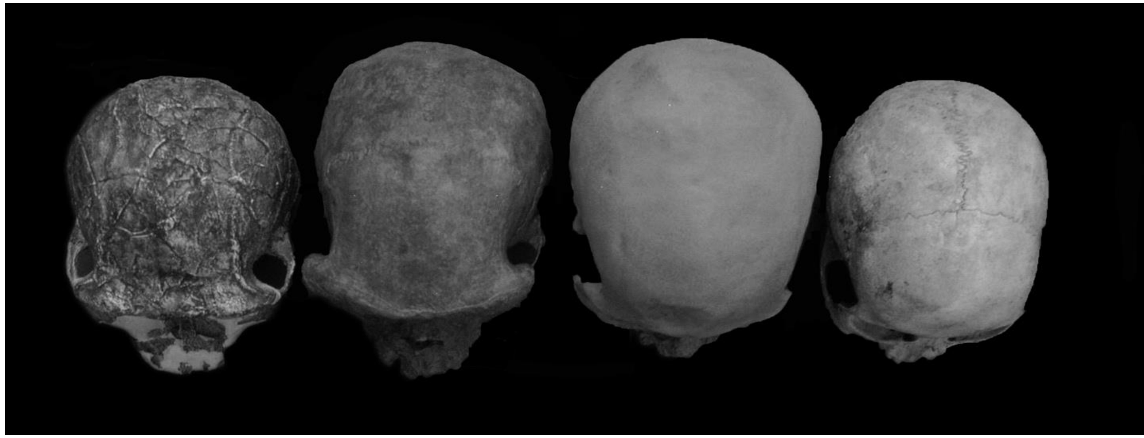
Advent of Agriculture (~10,000 ya)



http://www.britannica.com/EBchecked/media/106759/Painting-of-herdsmen-and-cattle-Tassili-n-Ajjer-Algeria

Offspring numbers increase, by at what cost?

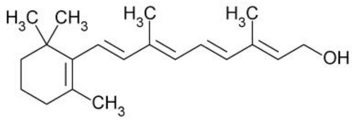
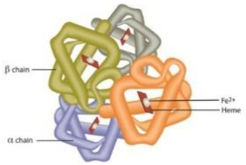
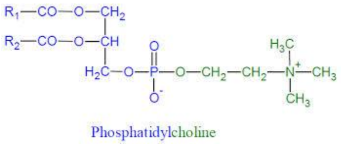
- Life expectancy ↓ from 40 to 20 yr
- Human height ↓
- Infection ↑
- Brain size ↓



H. erectus (1.6 mya), *H. heidelbergensis* (300,000 ya), *H. sapiens Cro-Magnon* (30,000 ya;), modern *H. sapiens*

(DeSilva et al. unpublished)

Food matrices: the importance of packaging

Limiting nutrient	ASF matrix	ASF vs. plant absorption rate
Vit A →		12-24x (ug)
Iron →		2x (mg)
Zinc →		2x (mg)
Choline →		?

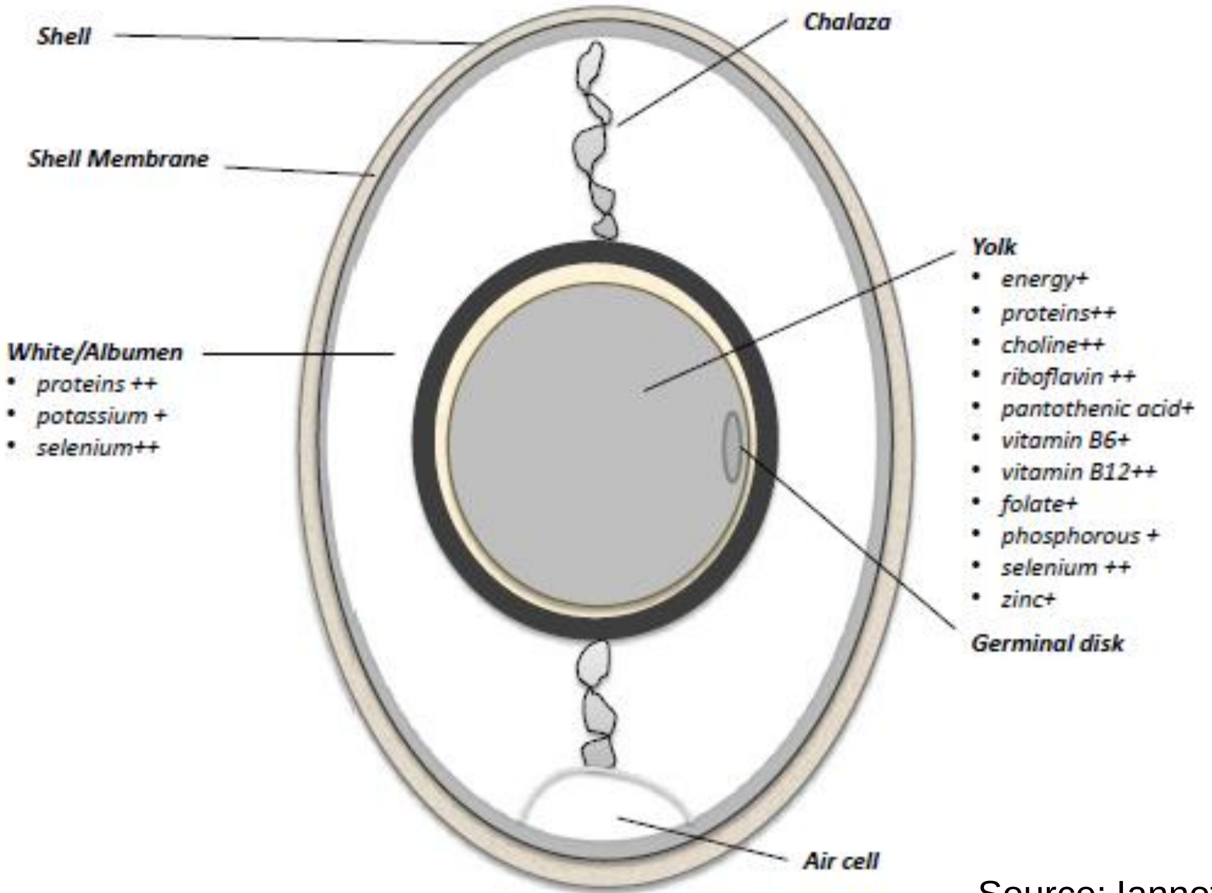
E3 Nutrition Lab – animal source foods

Economically affordable
Evolutionarily appropriate
Environmentally sustainable

Eggs, Milk, Fish

- First foods: designed to sustain and support early life, entirely
  - Complete set of nutrients and other bioactive factors

Egg = >50% of daily nutrients (++) and 20-50% (+) for breastfed infant



Source: Iannotti et al. *Nutrition Reviews* 2014

EVIDENCE

Synthesized evidence

- Lancet Series: *Maternal and Child Nutrition* (Bhutta et al. 2013)
  - Assessed 43 nutrition-related interventions
  - Literature **replete for *nutrition-specific*** (micronutrient supplementation, fortification, LNS, breastfeeding), but **limited for *nutrition-sensitive*** (food/diet, agriculture/livestock, education, etc.)
  - Provision of complementary food in food insecure populations **0.39 SMD in HAZ**; no effects on stunting reduction

- Cochrane Review ASF for growth in children 6-59 mo (Eaton et al. 2019)
  - Only 6 studies (n=3,076 children) from China, DRC, Ecuador, Guatemala, Pakistan, US, and Zambia
    - 3 reported increased height & weight with ASF vs. cereal-based foods/no intervention
    - 1 reported growth in height & weight gain in meat vs. dairy

Lulun Project

- **Objective:** Test the efficacy eggs introduced early in complementary feeding period on growth and nutrient biomarker outcomes (n=163)
  - **Primary outcomes**: biomarkers of choline, betaine, vitamin B_{12}, fatty acids, anthropometry and growth
  - **Secondary outcomes**: acceptability, dietary intakes, and morbidities, amino acids, growth factors

The Lulun Project

- RCT
  - **Cotopaxi:** mixed indigenous, high baseline stunting
  - **Intervention**: 1 egg/day for 6 mo, eggs purchased locally
  - **Longitudinal follow-up:** baseline (6-9 mo), endline (12-15 mo)
  - **Social marketing:** ownership, participation, compliance

- Mixed methods
  - **Quantitative**: caregiver surveys, anthropometry, GPS
  - **Biomarkers**: LC/MS/MS at Wash U, ELISA at NETLAB
  - **Qualitative**: grounded theory, structured observations, focus groups, and in-depth interviews

lulun project

Social marketing: ownership, participation, and adherence

Growth effects: GLM models

TABLE 2 Effect of the Intervention on Child Growth in a Randomized Controlled Trial of Eggs in Ecuador

	Baseline		End Point		Effect Size or PR		Effect Size or PR	
	Control (*n* = 82)	Egg (*n* = 78)	Control (*n* = 73)	Egg (*n* = 75)	Unadjusted		Adjusted[a]	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	β (95% CI)	*P*	β (95% CI)	*P*
LAZ (SD)	−1.71 (0.92)	−2.09 (1.08)	−1.71 (1.00)	−1.39 (1.35)	.64 (0.40–0.89)	<.001	.63 (0.38–0.88)	<.001
WAZ (SD)	−0.40 (0.92)	−0.91 (1.24)	−0.55 (0.85)	−0.34 (1.06)	.71 (0.53–0.90)	<.001	.61 (0.45–0.77)	<.001
WLZ (SD)	0.86 (0.99)	0.55 (0.99)	0.36 (0.81)	0.45 (0.84)	.42 (0.20–0.65)	<.001	.33 (0.14–0.51)	<.001
BMIz (SD)	0.80 (1.00)	0.42 (1.10)	0.64 (0.82)	0.68 (0.86)	.45 (0.20–0.70)	<.001	.29 (0.08–0.49)	.006
	%	%	%	%	PR (95% CI)[b]	*P*	PR (95% CI)[b]	*P*
Stunted	26 (32)	37 (47)	29 (40)	21 (28)	0.70 (0.44–1.12)	.14	0.53 (0.37–0.77)	.001
Underweight	4 (5)	10 (13)	5 (7)	4 (5)	0.78 (0.22–2.80)	.70	0.26 (0.10–0.70)	.008

Table shows results for end-point mean (SD) anthropometric measures and prevalence (no. [%], of undernutrition), as well as GLM modeling for unadjusted and adjusted effect size and PR for anthropometric outcomes, by group.

[a] Adjusted for child age, sex of the child, and baseline anthropometry for the same dependent variable.

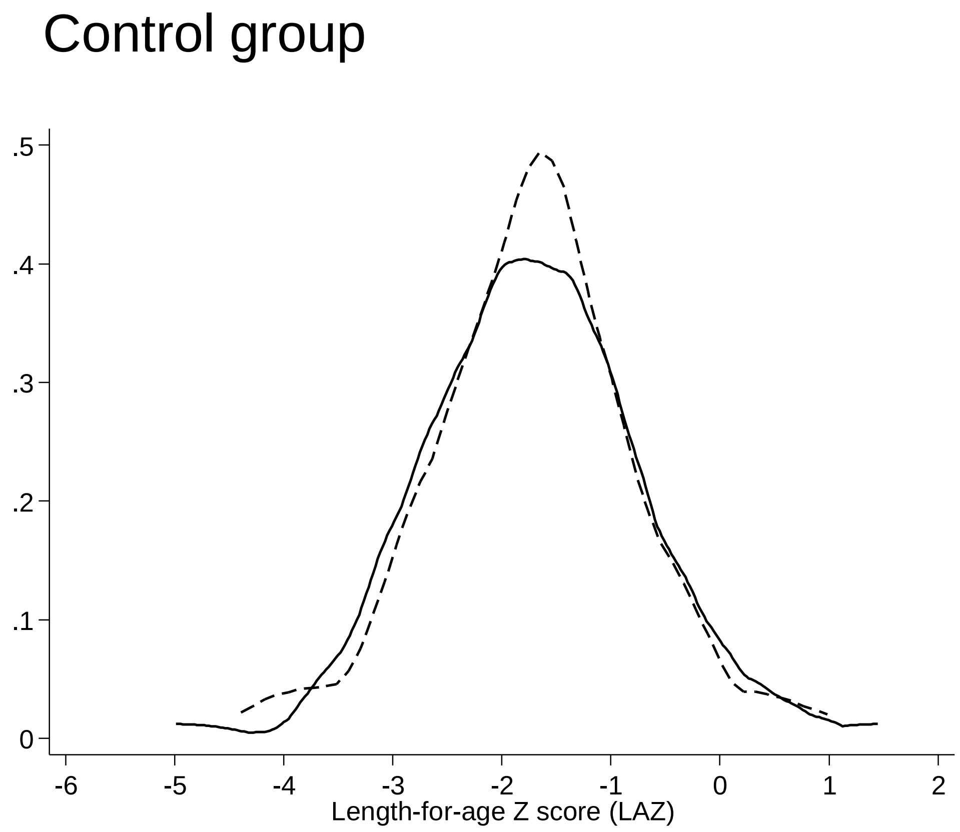
[b] PR was estimated using GLM with robust Poisson.

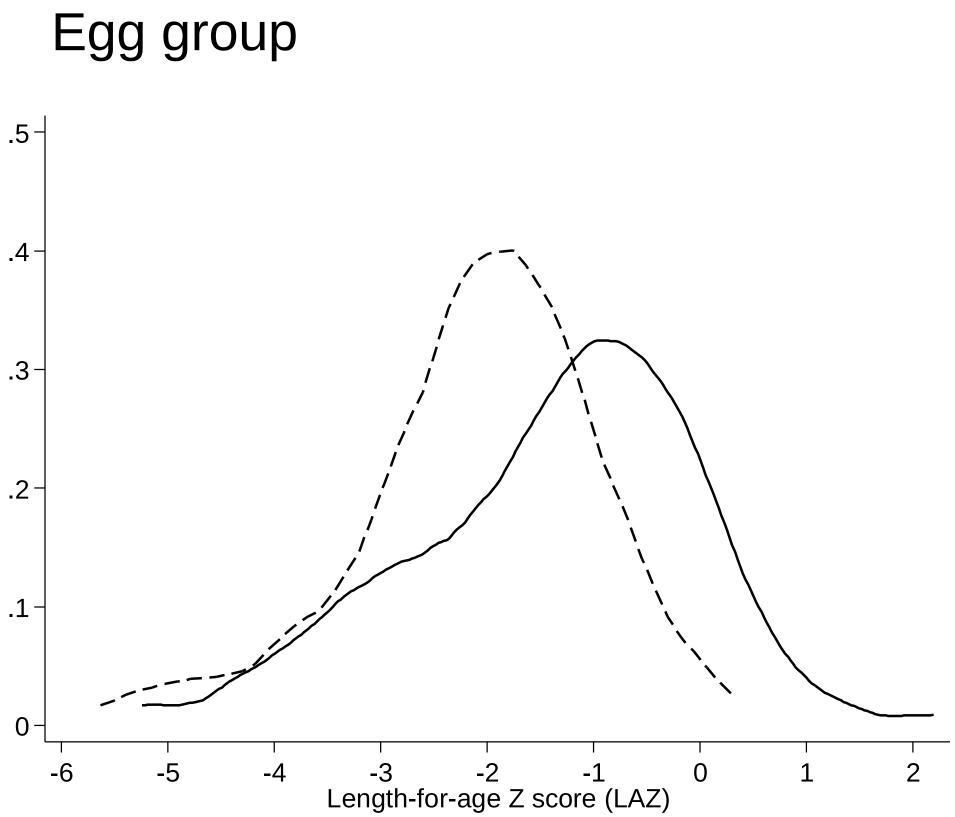
(Iannotti et al. *Pediatrics 2017)*

lulun project

Washington University in St. Louis
Brown School

Egg increased linear growth by 0.63 LAZ, reduced stunting 47%





baseline (dashed); endline (solid)

(Iannotti et al. *Pediatrics 2017)*

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Egg increased biomarkers of brain development

- **Choline → 0.35** (95% CI: 0.12, 0.57)
  - cell membrane (phosphatidylcholine); neurotransmission (acetylcholine); memory & learning (hippocampus); gene expression (betaine to methionine)

- **Docosahexaenoic acid (DHA) → 0.43** (95%CI: 0.13, 0.73)
  - predominant n-3 fatty acid in the brain
  - neurogenesis, neurotransmission, myelination, synaptic plasticity

- Methionine, betaine, TMAO, DMA, amino acids

(Iannotti et al. *AJCN 2017*)

Pilot study – Ecuador (preliminary, unpublished results)

-	Mean Z Scores (SD)			WHO Mean Percentiles (SD)		
	Male (n = 25)	Female (n = 20)	All (n = 47)	Male (n = 25)	Female (n = 20)	All Mean (n = 47)
Biparietal Diameter	-0.65 (1.00)	-1.32 (1.19)	-0.95 (1.11)	35 (27.2)	19.75 (23.4)	28.05 (26.22)
Head Circumference	0.45 (0.87)	-0.02 (1.07)	0.26 (0.97)	41 (33.4)	26.50 (24.6)	35.32 (29.9)
Abdominal Circumference	0.06 (0.86)	0.08 (1.00)	0.08 (0.90)	38 (30)	42.75 (27.3)	40.32 (28.05)
Femur Length	-0.21 (0.86)	-0.30 (1.39)	-0.22 (1.10)	39 (29.25)	46.75 (34.75)	43.51 (31.96)
Humerus Length				41.82 (28.29)	34.84 (35.64)	38.44 (30.91)
Estimated Fetal Weight				39.90 (31.75)	45.25 (33.86)	42.61 (31.76)

Regression modeling:

- head circumference, biparietal diameter, & cerebellar diameter associated with dietary intake of animal source foods (seafood, eggs)

KENYA

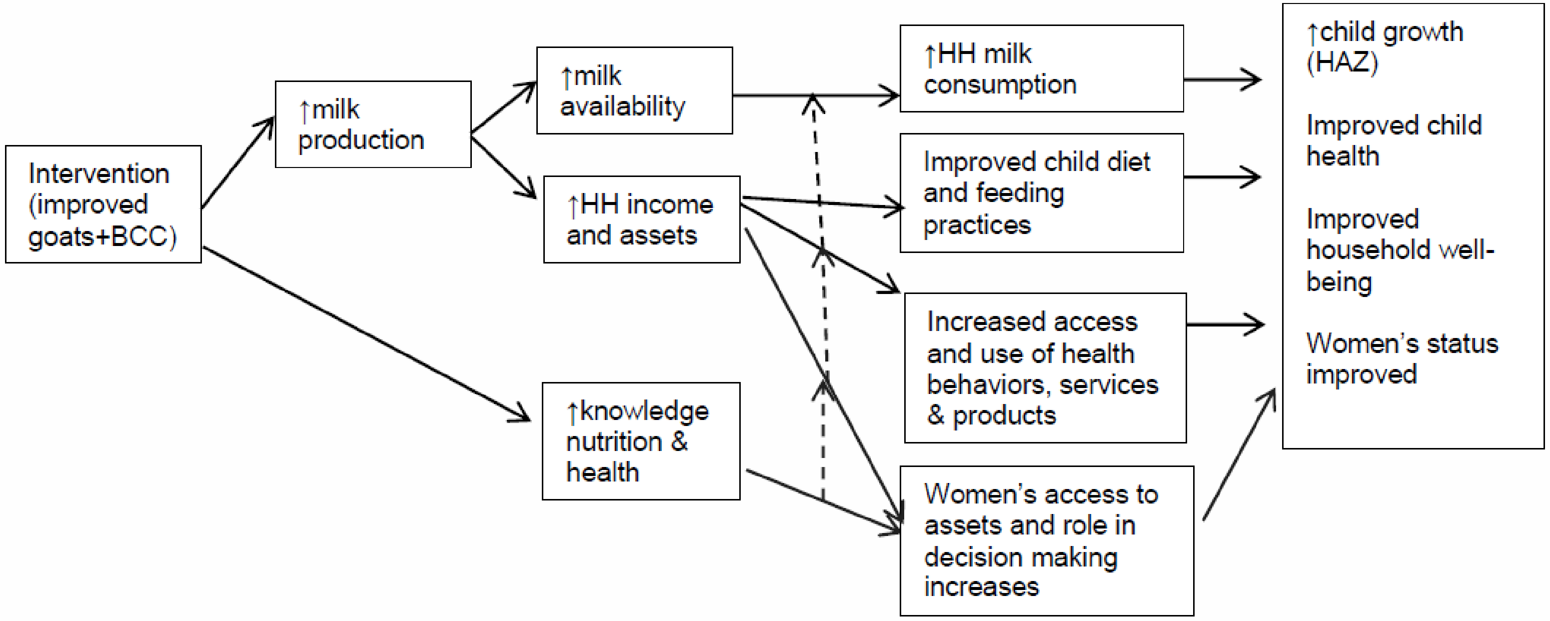
Pastoralists & milk nutrition

- 200 million pastoral and agro-pastoral people in drylands (ILRI)
- 1980s-1990s milk >50% of diets Turkana, Rendille, Maasai, and Borana; 30% in other agro-pastoralist populations of Sudan and Afghanistan
- Milk provides calcium, magnesium, zinc, selenium, riboflavin, vit B12, whey/casein proteins, linoleic acid and α-linolenic fatty acids, IGF-1

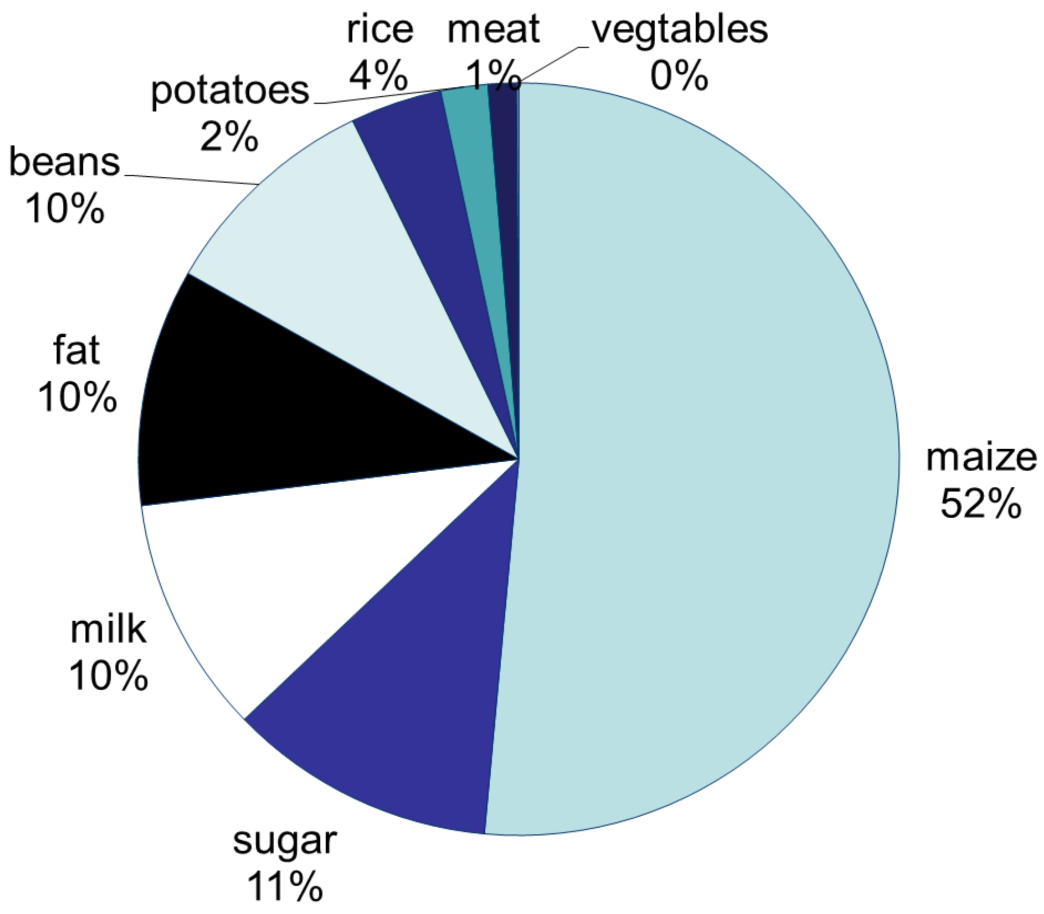
Pathways to nutrition impacts

- Livelihood transition: ↓ Land access & ↑ Sendentarization
- 2 comparable communities: Siambu, livestock; Mbaringon: cultivation
- Longitudinal data - 2000, 2005, 2010, 2012

Figure 9: Causal Pathways



Maize dependency - % daily kcals



Food source of nutrients

Table 3. Food group source of nutrients (%), 2010

	Energy	Vitamin A	Vitamin B_{12}	Vitamin C	Folate	Iron	Zinc
Maize	49	34	0	0	27	60	51
Rice	5	0	0	0	7	5	13
Potatoes	2	0	0	33	2	3	1
Beans	11	0	0	0	57	27	21
Meat	1	0	6	0	0	2	3
Milk	10	57	94	50	6	2	11
Vegetables	0	9	0	17	1	1	0
Fat	9	0	0	0	0	0	0
Sugar	13	0	0	0	0	0	0

Iannotti and Lesorogol *Current Anthropology* 2014

Livestock ownership improves nutrient intake

- **Findings:**
  - Livestock ownership increased nutrient adequacy for vitamin A, B_{12}, and zinc (P<0.001) (Iannotti and Lesorogol *CA* 2014)
  - Milk consumption increased BMI z scores among youth (P<0.001) (Iannotti and Lesorogol *AJPA* 2014)
  - Cattle and chicken ownership increased dietary diversity (P<0.001)

- **Conclusion:**
  - Support livestock development among pastoralist households for child milk consumption and nutrition

- **Next steps:**
  - Samburu study to examine mineral status of adolescent pastoralists – highlands vs lowlands

SecureFish Kenya - FIL

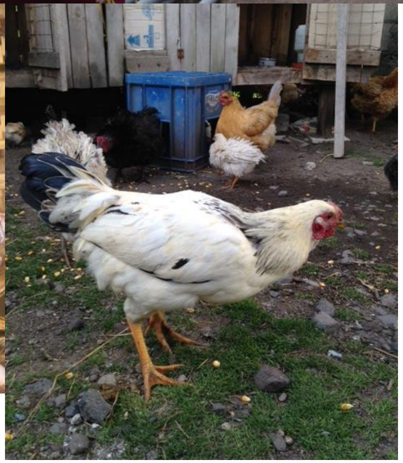
- Problem
  - Coastal communities stunting 39% (26% national average) (DHS)
  - Kenyan coastal fisheries overexploited; ↓4x in catch since 1980s (Samoilys et al. 2017)

- Design & Methods
  - Site inclusion criteria: proximity to *Marine Protected Area*; Beach Management Units divided by coastal highway
  - Fishers (n=100) and non-fishers (n=100)
  - Mixed methods: qualitative, quantitative, Wildlife Conservation Society data

Partners: Wash U, University of Rhode Island, Egerton University, Pwani University, MSU

ASF Research – context matters





- **Malawi**
  - Mazira RCT replication study: egg effects on growth, biomarkers, and child development → no effect on LAZ or stunting
  - High fish consumption; maize staple; limited social marketing
- **Ecuador**
  - Lulun II follow-up cohort → effect no longer present after 2 years; ASF interventions should be continued through childhood
  - Sustainability and scalability of egg nutrition: poultry production → barriers include soil quality, climate change
  - Evolutionary nutrition trial – fish, eggs, berries/greens in pregnancy

CONCLUSIONS

Global Nutrition Targets 2025 – ASF Contribution

1) Stunting →

2) Anemia →

3) Low birthweight→

	TARGET	BASELINE 2012	TARGET FOR 2025
1	40% REDUCTION IN THE NUMBER OF CHILDREN UNDER-5 WHO ARE STUNTED	162 million	≈100 million
2	50% REDUCTION OF ANAEMIA IN WOMEN OF REPRODUCTIVE AGE	29%	15%
3	30% REDUCTION IN LOW BIRTH WEIGHT	15%	10%
4	NO INCREASE IN CHILDHOOD OVERWEIGHT	7%	≤7%
5	INCREASE THE RATE OF EXCLUSIVE BREASTFEEDING IN THE FIRST 6 MONTHS UP TO AT LEAST 50%	38%	≥50%
6	REDUCE AND MAINTAIN CHILDHOOD WASTING TO LESS THAN 5%	8%	<5%

Key messages

1) Globally, 151 million young children have stunted growth & 250 million stunted development. Malnutrition primarily risk factor in 45% of all childhood deaths globally.
   - Biological and evolutionary rationale underpin the need for ASF in human nutrition

2) Evidence is limited for ASF
   - Previous studies focused on nutrient supplements, LNS, & fortification - with a small effect size of 0.39 HAZ
   - Lulun Project of one egg/d ↑ LAZ by 0.63; ↑ biomarkers of brain development
   - Context matters: milk pastoralists; Mazira; fish coast; etc.

3) ASF show great potential for alleviating stunting
   - Global community strive for nutrition equity for planetary health
   - ASF contribute to Global Nutrition Targets & SDGs

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Community of Pastocalle

G. Reinhart photo

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lulun project