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Food systems transformation, animal-source foods consumption, inequality, and nutrition in Myanmar

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Abstract

This study traces the consumption of animal-source foods (ASF) during a period of rapid economic change and food system transformation in Myanmar. We use data from two nationally representative consumption surveys conducted in 2010 and 2015 and food composition tables to estimate the contributions of ASF to estimated average requirements (EARs) of key nutrients among population subgroups differentiated by geography and economic status. We find: (1) Little change in the average quantity of ASF consumed per individual, but substantial changes in the composition of the ASF consumed. (2) Increasing rural–urban and income-linked inequality in quantities of ASF and associated nutrients consumed. (3) Declines in the adequacy of intakes of five out of eight micronutrients (calcium, iron, zinc, thiamine, vitamin B12) and small increases in two (selenium and vitamin A), due to the changing composition of ASF; most importantly, reductions in the supply of diverse aquatic foods from capture fisheries and increasing availability of intensively reared chicken. (4) Elevated levels of ASF-derived total fat and sodium consumption among better-off consumers, suggesting an emerging triple burden of malnutrition. We review the implications of these results for food security, nutrition-sensitive policies and interventions beyond Myanmar.

Keywords Animal source foods · Food systems · Triple burden of malnutrition · Nutrition-sensitive approaches · Myanmar

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1 Introduction

The triple burden of malnutrition - undernutrition, overnutrition and micronutrient deficiencies - persists at unacceptably high rates globally and is deepening (Global Nutrition Report, 2020). Prior to the onset of the COVID-19 pandemic, the rate of progress was inadequate to reach the United Nations objective to end all forms of malnutrition (UN Stats, 2020). Progress was further hampered by the pandemic and measures to contain it, adding 83 – 132 million people to the 820 million already undernourished globally (FAO et al., 2020; HLPE, 2020).

Food-based interventions seek to address the triple-burden of malnutrition by optimising diet quality and diversity to increase consumption of nutrient-dense foods, and encourage energy and macronutrient intakes at levels appropriate to avoid under- and over-nutrition (Willett et al., 2019).

Animal-source foods (ASF) are a key group of nutrient-dense foods that provide highly bioavailable micronutrients such as iron, zinc, B12, vitamin A, vitamin D3, iodine, calcium, folic acid, and essential fatty acids. These are crucial for child development and human health, yet inadequate in the diets of nearly 800 million individuals worldwide (Adesogan

et al., 2020; GAIN, 2020; Dasi et al., 2019; Headey et al., 2018; Leroy & Frongillo., 2007).

However, ASF are not homogenous in their micronutrient contents. For example, beef and eggs contain high levels of iron and vitamin A, respectively, and some fish and fish based-products are rich sources of calcium and vitamin B12 (see Table 5 for examples). Moreover, changes in the supply of ASF affect their prices and accessibility to consumers (Belton et al., 2018a, b; Mahrt et al., 2023). This variability makes it important to consider macro- and meso-scale changes occurring in food systems in relation to the consumption of individual foods, and the implications of these changes for nutrition.

At the same time, overconsumption of ASF can drive negative human health and environmental outcomes, and increasing meat consumption is associated with the rising burden of non-communicable disease (NCDs) in middle-income countries (Schmidhuber & Shetty, 2005). This tendency makes striking a balance between under- and overconsumption of different ASF an important objective for policies seeking to address the triple burden of malnutrition by changing diets.

Diets in many low- and middle-income countries (LMICs) are transforming rapidly in response to changes in income, urbanization, levels of physical activity, opportunity costs of time, and food environments (Reardon et al., 2021). This is resulting in a deepening triple burden of malnutrition in locations where rapidly increasing overconsumption of energy and unhealthy foods coexists with persistent undernutrition (Mayén et al., 2014; Popkin et al., 2001; Schmidhuber & Shetty, 2005).

These trends are apparent in Myanmar, one of Asia's least economically developed countries, which underwent a dramatic transformation linked to economic and political reforms between 2011 and 2019 (Belton & Filipski., 2019). During this period, rates of economic growth averaged 7.2% per year, accompanied by rapid urbanisation (World Bank, 2019), and the share of people living below the poverty line fell sharply, from 48% in 2005 to 25% in 2017 (World Bank, 2019).

Indicators of micronutrient deficiencies improved during Myanmar's brief reform period, but much more slowly than indicators of economic welfare (Rammohan et al., 2018). For example, stunting rates among children only declined by 13 percentage points between 1990 to 2018, and remained high by the end of this period, at 27% (Hlaing et al., 2019). Anemia rates among primary school children and pregnant women also remained persistently high, at 51% and 40%, respectively, while 19% of adult men and 14% of adult women were underweight (MoHS & ICF, 2017).

At the same time, rates of overweight (11% men, 23% women) and obesity (2% men and 7% women) increased, (MoHS & ICF, 2017; Hong et al., 2018; GNR, 2020). The occurrence of associated NCDs such as diabetes, cardiovascular diseases, and some cancers began to rise (MoHS & ICF, 2017; GNR, 2020). Myanmar's economic growth prior to 2020 was unevenly distributed. The welfare of the poorest

10% of the population changed less than that of the average household (World Bank, 2017; Okamoto, 2020), and lived experiences of poverty, including severe food insecurity, remained more widespread than suggested by improvements in 'macro' economic indicators (Shaffer, 2015). Stunting rates among children from poor households remained much higher (38%) than in those from better-off households (16%) and higher in rural areas than urban (MoHS & ICF, 2017).

Even before the crisis in Myanmar that began in 2020 with the onset of the COVID-19 pandemic and deepened in 2021 with the military coup, many households were vulnerable to falling into poverty and food insecurity in the face of shocks (Ferreria et al., 2021), and more than half of the population could not afford the cost of a nutritious diet (Mahrt et al., 2019). The economy contracted by 18% in 2021, following very weak growth in 2020, making the economy around 30% smaller than it would have been in the absence of COVID-19 and the coup (World Bank, 2021). Human welfare declined dramatically as a result, and more than half the population is presently estimated to fall below the poverty line (MAPSA, 2022; Diao & Mahrt, 2020).

Drawing together these themes, this study aims to answer the following applied empirical question: How were ASF consumption patterns in Myanmar and the intakes of micronutrients associated with them changing in the decade prior to the crisis, with what implications for nutritional adequacy, for which population subgroups? We differentiate between population sub-groups in terms of rural and urban location and economic status, because these variables tend to be important determinants of nutrition equity. Answering this question can inform more effective public health strategies aimed at addressing the triple burden of malnutrition.

We analyse datasets from two nationally representative consumption surveys conducted in Myanmar in 2010 and 2015, and a self-compiled food composition dataset. This analysis allows us to estimate temporal changes in apparent consumption of ASF and ASF-derived nutrients and compare them with estimated average requirements (EARs). This approach allows us to address a lack of data from costly individual nutrient intake studies that are required to inform effective nutrition and food systems policies, with potential methodological applications in many countries beyond Myanmar.[1]

We find evidence of: (1) Little change in the average quantity of ASF consumed per individual, but substantial changes in the composition of ASF, favoring increased poultry consumption. (2) Increasing rural–urban and income-linked inequality in quantities of ASF consumed. (3) Declines in the adequacy of intakes of key micronutrients due to the changing composition of ASF consumption. (4) Elevated levels of

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[1] See Ignowski et al. (2023) for an application of a similar approach to the analysis of dietary adequacy in Tanzania.

Table 1 Characteristics of surveyed households

Characteristics	ILHCA 2010		MPLCS 2015	
Total number of HH	18,659		3,619	
Rural HH n (% total)	13,074	73.4	2,354	72.7
Urban HH n (% total)	5,515	26.6	1,265	27.3
AE per HH	5.2		4.9	

ASF-derived total fat and sodium consumption among better-off consumers. These results suggest an emerging triple burden of malnutrition during the period studied.

The remainder of the paper is as follows. First, we describe the data and methods used. Second, we present results on changes in the quantity and composition of ASF intakes in Myanmar between 2010 and 2015, and estimates of the changing contributions of ASF to nutrient adequacy. Third, we interpret these results with respect to implications for nutrition and health in Myanmar and other rapidly transforming LMICs. The final section concludes by considering some of the broader implications of these findings for nutrition-sensitive policy beyond Myanmar.

2 Data and methods

2.1 Survey datasets

Household consumption surveys are an underexploited resource to understand gaps in dietary data in the absence of individual diet surveys (Fiedler et al., 2012). We estimated ASF consumption in Myanmar, using datasets from two nationally representative household surveys; the Integrated Household Living Conditions Assessment Survey (IHLCA) from 2009/10 (IHLCA, 2011), and Myanmar Poverty and Living Conditions Survey (MPLCS) from 2015 (World Bank, 2017). IHLCA 2009/10 was conducted in two rounds. We retained data from the first round only as the survey months corresponded most closely to those of MPLCS (Table 1). Each survey included a detailed household consumption expenditure module in which respondents were asked whether the household had consumed listed food items during the preceding seven days of the survey, and the quantity of each food item consumed.

Both surveys were designed to estimate national and subnational poverty rates. IHLCA 2010 deployed a stratified multi-stage sample design with 62 districts of the country as the strata, and a second stage sampling unit of ward (for urban districts) or village tract (for rural districts) (IHLCA, 2011). The sample was nationally representative, and representative at the state and region level for rural and urban households (Myanmar has 14 states/regions). The 2015 MPLCS sample design was based on the 2014 Census, divided into zones and enumeration areas to determine the strata (World Bank, 2017). The survey was nationally representative, representative at the level

Table 2 National average annual consumption of ASF, 2010 and 2015 (kg/capita/year)

	2010		2015	
	Mean (kg/ capita)	SE	Mean (kg/ capita)	SE
Freshwater fish	11.0	0.48	9.2	0.39
Marine fish	1.7	0.24	2.6	0.23
Shrimp/squid/other seafood	1.2	0.14	0.9	0.08
Dried aquatic products	2.6	0.14	2.2	0.11
Fermented aquatic products	4.6	0.20	4.5	0.17
Subtotal aquatic ASF	*21.1*		*19.5*	
Eggs	4.9	0.18	5.7	0.14
Chicken	4.2	0.20	6.9	0.22
Pork	5.8	0.26	4.4	0.22
Meats (all others)	3.8	0.21	2.6	0.24
Fresh milk	0.9	0.15	1.4	0.15
Subtotal non aquatic ASF	*19.5*		*21.0*	
Total all ASF	**40.6**		**40.5**	

of 4 agroecological zones (Coasts, Delta, Dry Zone, and Hills and Mountains) each comprised of several states/regions, and representative for rural and urban households. Hence, the total sample size of MPLCS is much smaller than that of IHLCA (Table 1). Differences in the two surveys sampling strategies mean direct statistical comparison of results between the 2010 and 2015 surveys was not possible. Differences among subgroups within each of the two surveys (e.g., differences between rural and urban consumption) were tested for significance.

We constructed household consumption variables to convert household consumption to adult equivalents (AE) using methods from Mahrt et al. (2019). This method assigns household members with an equivalence factor based on age and sex-specific energy requirements relative to a reference adult, then divides household consumption by the number of AE in the household (Waid et al., 2017). Limitations of this method are that we cannot account for intra-household distribution of food and we do not assume AE represents true individual intake within a household.

Consumption aggregates used to construct expenditure quintiles were computed by the authors for IHLCA 2010, following standard methods (Deaton & Zaidi, 1999). The MPLCS 2015 dataset supplied by the World Bank included a consumption aggregate variable. Consumption means for individual food items were adjusted using survey weights. Outliers were identified compared to an upper bound total energy cut-off and cleaned from the dataset. ASF consumption quantities were subsequently reviewed at the item level and found to fall within acceptable ranges. Data in Table 2 are presented as annual per capita consumption of whole portions of ASF to facilitate easy comparison with commonly reported international values (e.g., the FAO food balance

sheets). All other results are reported as daily AE consumption of edible portions - i.e., after adjusting for inedible portions discarded during cleaning and preparation for cooking (e.g., fish scales, viscera), and plate waste (e.g., bones).

ILHCA and MPLCS identified 36 and 37 groups of aquatic food items, respectively, comprised mainly of fresh and processed freshwater and marine fish and shrimp, as well as six types of meat, three egg varieties, fresh milk, and 'other meat, dairy, eggs'. We excluded condensed milk from the ASF category due to the high added sugar and oil content. Milk powder was observed in very small volumes in the 2010 data set and not included in the 2015 survey, so was also excluded from the analysis.

The survey categories did not allow for accurate decomposition of fish by source into those originating from aquaculture and capture fisheries. Consumption of foods away from home was not reported in a format that permitted differentiated analysis of their composition. ASF eaten away from home are thus not included in the analysis but would contribute further to total ASF consumption.

In addition, we make use of weekly timeseries data on ASF prices collected by the Central Statistical Office (CSO) between April 2008 and February 2018 from retail markets across Myanmar. We adjusted these nominal prices to account for inflation using the general consumer price index (also supplied by CSO), and converted them to an index, where the price of all ASF for April 2008 was equal to 100, with an increase(decrease) of one point in subsequent months equivalent to a 1% increase(decrease) in real price. This information allows us to compare the evolution of prices of different categories of ASF over time, independent of the effects of inflation, and offers important contextual information with which to interpret results from the two household surveys.

2.2 Nutrient composition data

ASF items were matched and converted to nutrients at the food item level (45 total items), then reaggregated for ease of comparison in the paper. Matching of the food items reported in the datasets to food composition data was conducted in line with FAO/INFOODS Guidelines (2012). In the absence of current Myanmar food composition tables, USDA food composition tables (2016) were utilised to derive total energy estimates and wastage factors for meats, chicken, eggs, and milk. The USDA tables did not include suitable matches for aquatic species.

A literature review was conducted to match the varied aquatic food items reported in the dataset to known nutrient composition values. Data from published sources (Bogard et al., 2015) and databases (FAO INFOODS Global Food Composition Database, 2016, 2017; Mahidol University

ASEAN Food Composition Database, 2014; Judprasong et al., 2015; Longvah et al., 2017) were used to obtain estimates of the nutrient composition of the 37 fresh and processed aquatic foods. Fish species reported in Myanmar were matched with the same or similar species from geographically similar countries for which nutrient composition data were available, following advice elicited from fisheries scientists. Conversion to edible portions was based on species-specific coefficients reported by Bogard et al., (2015). The nutrient composition table compiled for this analysis is available in the attached supplementary materials. A simplified nutrient table is available in the Annex (Table 5).

Details of the following dietary components were extracted from the literature: energy, protein, fat, moisture, ash, iron, zinc, calcium, iodine, selenium, phosphorous, magnesium, sodium, potassium, manganese, copper, vitamin B12, vitamin D3, vitamin E, vitamin A and essential fatty acids. Where a sample had missing data for a single nutrient, the value was 'borrowed' from the next closest species match. Data on macronutrient composition, iron, zinc, calcium, and vitamin B12 were most complete across the nutrient composition results. Data on essential fatty acids was most incomplete and thus could not be estimated here. Estimated nutrient composition values were difficult to obtain for some processed aquatic foods, particularly fermented fish pastes unique to Myanmar. The recipes and species used in such products vary widely across the country and represent an important area for further investigation and composition analysis.

Although mean food and nutrient intakes per AE are not a replacement for the 'gold standard' of individual dietary assessment methods, they offer a means of deriving estimates in the absence of such surveys. We compare estimated nutrient consumption from ASF per AE to estimated average nutrient requirements (calculated as the mean EAR of an adult man and woman). EARs are the average daily nutrient intake estimated to meet the requirements of half of the healthy individuals in a particular life stage and gender group, and are suitable for assessing population groups (Allen et al., 2020; Gibson, 2005).

Harmonised average requirements based on the WHO/FAO recommended nutrients intakes (RNIs) for individuals (WHO/FAO, 2004) were applied (Allen et al., 2020). This measure supports comparisons of the extent to which ASF contribute to nutrient adequacy among population subgroups, but does not indicate the (in)adequacy of micronutrient intakes for an individual. Where EARs are not applicable, e.g., sodium was compared to the adult upper limit (UL) and macronutrients within their respective reference range (WHO, 2020; FAO/WHO/UNU, 2002).

Statistical analysis was completed using STATA (version 16.1). Pairwise comparisons between mean rural and urban consumption were made to the 95% confidence interval (C.I.) for each ASF group, within each respective survey

year. Linear regressions were used to compare the mean consumption of each ASF group across wealth quintiles.

3 Results

The following sub-sections present the results from our analysis of ASF consumption patterns and estimates of associated micronutrient intakes and their contributions to nutrient adequacy.

3.1 National ASF consumption trends

ASF contributed 32% of total food expenditure in 2010 (urban 33%, rural 31%), of which aquatic foods accounted for 13%, poultry and other meats 15%, and eggs 4%. The share of ASF in food expenditure declined slightly in 2015, to 29% (urban 32%, rural 27%). Aquatic foods' share of food expenditure remained stable at 13%, and meats and eggs declined slightly, to 12% and 3%, respectively. Part of this decline may be related to the increasing budget share of food away from home, up from 7 to 11%. The share of ASF in food expenditure ranged from 27% for households in expenditure Quintile 1 to 35% in Quintile 5 in 2010, and from 22% to 34% in 2015 (see Table 6).

In both survey years, more than 90% of respondent households had consumed at least one ASF within the seven days preceding the survey. Aquatic foods were the most frequently consumed ASF, reported by 93% of households in 2015. Meat and egg consumption was also common, both reported by 76% of households in 2015.

Aquatic foods accounted for around half the quantity of ASF consumed. Unadjusted annual aquatic food consumption per capita (i.e., before conversion to edible portions and adult equivalents) was close to the global average level of consumption of around 20 kg/capita/year (FAO, 2020), in both years (Table 2). Freshwater fish, originating from both capture fisheries and aquaculture, made up half of the aquatic food group. Processed aquatic products accounted for one-third of the quantity of aquatic foods consumed. This group of products includes dried fish and shrimp, and fermented pastes and sauces that are key ingredients in Myanmar cuisines.

In both survey years, the next three most consumed ASF were eggs, pork, and chicken. However, the quantities consumed and their relative importance changed markedly between survey rounds. In 2010, pork was the most consumed of the three ASF at 5.8 kg/capita/year, followed by eggs (4.9 kg/capita/year), and chicken (4.2 kg/capita/year). By 2015, the relative importance reversed, with individuals consuming an average of 6.9 kg/capita/year of chicken, 5.7 kg/capita/year of eggs, and only 4.4 kg/capita/year of pork. Consumption of all other meats declined slightly. Small quantities of fresh milk were consumed in both years,

but consumption rose between rounds to reach 1.4 kg/capita/year in 2015.

3.2 Sub-national ASF consumption trends

In this and subsequent sub-sections, we report consumption in edible portions per adult equivalent per day (g/AE/day) to account for differences in household demography and variability in the edible parts of different ASF. Several themes emerge when examining ASF consumption by different population groups and over time (Table 3).

First, national daily average consumption per capita of all ASF combined remained constant between 2010 and 2015, at around 103 g/AE/day.

Second, rural and urban ASF consumption diverged between 2010 and 2015. Urban dwellers consumed about 3% more ASF than their rural counterparts in 2010, rising to 20% more in 2015. This widening gap was caused by an increase in average urban levels of ASF consumption and a slight reduction in rural consumption.

Third, differences in ASF consumption across Myanmar's different geographical zones reflect variability in local supply, culinary traditions, and purchasing power. The Hills and Dry Zone consume the least ASF, the Delta and Yangon consume the most, and the Coasts are intermediate. These differences are driven primarily by consumption of aquatic foods, which are by far the highest in the Delta, Coasts, and Yangon, where most of Myanmar's fish is produced. Consumption of other types of ASF is fairly similar across zones, apart from Yangon – the location of Myanmar's largest city – where consumption of chicken, eggs and milk is markedly higher than in all other zones.

Fourth, as expected, there was a significant gap in consumption of all ASF groups between poorer and wealthier groups in both survey years. The wealthiest 20% of households (expenditure quintile 5, abbreviated as "Q5"), consumed 3.6 times more ASF than the poorest 20% of households (Q1), in 2015 (171.5 vs 47.8 g/AE/day). Pairwise comparisons confirmed that the gap in consumption between Q5 and Q1 was statistically significant for all ASF groups, at the 95% confidence interval in both years.

Fifth, the gap in average ASF intakes between upper and lower expenditure quintiles grew over time, suggesting deepening inequality in access to nutritious foods. In 2010, individuals in Q5 consumed 110 g/AE/day more ASF per day than those in Q1. This gap grew to 124 g/AE/day in 2015, an increase of 13% (Table 3). Importantly, this change was due to a simultaneous slight decrease in ASF consumption by individuals in Q1 (-4 g/AE/day), while consumption by those in Q5 rose by 10 g/AE/day, so ASF consumption among the lowest income consumers declined in absolute terms. Although consumption of eggs, chicken, and milk increased for the poorest 20% households in 2015, this

Table 3 Mean ASF consumption by location and expenditure quintile, 2010 and 2015 (g/AE/day)

2010	Aquatic foods (g)	SE	Eggs (g)	SE	Chicken (g)	SE	Pork (g)	SE	Meats (g)	SE	Fresh milk (g)	SE	Total ASF (g)	SE
National	55.1	1.9	12.9	0.5	8.5	0.4	14.4	0.6	9.1	0.5	2.6	0.4	102.5	2.5
Rural	54.9	2.3	11.7	0.4	8.2	0.5	15.9	0.7	9.3	0.6	1.5	0.2	101.6	3.1
Urban	55.7	2.7	16.2*	0.8	9.2	0.4	10.0*	0.7	8.4	0.9	5.5*	1.4	105.0	4.6
Agro-ecological zone														
Hills	36.3	5.42	12.2	0.80	11.3	0.78	17.7	1.26	8.3	0.67	1.8	0.55	87.7	7.97
Dry	41.5	1.83	11.7	0.56	7.5	0.84	14.4	1.01	14.2	1.09	2.6	0.50	91.9	3.84
Delta	76.7	2.69	14.8	0.73	8.4	0.55	17.4	1.18	5.6	0.61	1.6	0.40	124.5	3.67
Coastal	53.0	3.87	7.1	0.60	7.0	0.81	8.1	1.14	6.4	0.85	1.8	0.43	83.4	5.69
Yangon	63.0	5.10	16.6	1.92	8.8	0.89	8.6	1.70	6.7	1.62	6.3	3.08	110.1	10.12
Expenditure quintile														
Q1	30.4	1.4	6.1	0.3	3.2	0.3	7.2	0.8	4.4	0.4	0.4	0.2	51.7	1.3
Q2	42.9	1.7	9.7	0.4	5.8	0.4	12.1	0.6	7.3	0.4	0.8[a]	0.2	78.6	1.9
Q3	53.0	1.7	12.4	0.3	7.9	0.5	14.6	0.7	9.7	0.7	1.5	0.3	99.0	2.1
Q4	64.6	2.1	15.5	0.4	10.8	0.5	18.1	0.8	10.5	0.8	2.1	0.3	121.5	2.5
Q5	84.7	3.2	20.7	0.6	14.6	0.5	19.9	1.1	13.4	1.0	8.1	1.6	161.7	4.8
Mean difference Q5 - Q1	54.3**		14.6**		11.3**		12.7**		9.1**		7.7**		110.0	

2015	Aquatic foods (g)	SE	Eggs (g)	SE	Chicken (g)	SE	Pork (g)	SE	Meats (g)	SE	Fresh milk (g)	SE	Total ASF (g)	SE
National	52.1	1.4	15.4	0.4	14.2	0.4	10.8	0.5	6.3	0.6	4.3	0.5	103.2	2.3
Rural	52.8	1.8	13.5	0.5	12.0	0.5	10.9	0.7	6.5	0.8	2.0	0.5	97.7	2.8
Urban	50.2	2.1	20.1*	0.6	19.9*	0.8	10.8	0.6	5.9	0.6	10.4*	1.1	117.2	3.7
Agro-ecological zone														
Hills	28.4	2.14	15.6	0.82	13.5	1.10	12.5	1.35	3.8	0.47	4.0	0.83	77.8	3.90
Dry	32.3	1.83	13.6	0.77	11.7	0.75	9.6	0.99	7.4	0.88	3.9	0.91	78.5	3.39
Delta	76.8	3.35	15.5	0.82	14.0	1.01	11.6	1.24	7.9	1.64	3.0	0.94	128.9	5.26
Coastal	68.9	4.43	11.8	0.78	10.6	1.02	8.3	1.19	4.6	0.74	2.2	0.51	106.4	6.14
Yangon	62.5	2.60	20.7	0.74	22.7	1.09	11.5	0.87	5.2	0.96	9.6	1.45	132.2	4.18
Expenditure quintile														
Q1	28.4	2.1	7.4	0.4	5.1	0.5	3.4	0.5	1.7	0.3	1.9	0.8	47.8	2.2
Q2	40.3	2.0	12.6	0.6	9.0	0.6	7.1	0.7	4.6[a]	0.8	1.5	0.5	75.0	2.6
Q3	51.5	2.1	14.3	0.7	12.1	0.7	10.7	1.1	6.6	0.9	1.5	0.4	96.7	2.7
Q4	63.1	2.5	18.6	0.8	17.8	0.9	13.4	1.0	7.4	0.8	4.7	0.8	124.9	3.8
Q5	77.0	3.1	24.0	0.7	27.2	1.1	19.6	1.1	11.5	1.1	12.2	1.3	171.5	4.6
Mean difference Q5 - Q1	48.6**		16.6**		22.2**		16.2**		9.8**		10.4**		123.7	

SE standard error, *AE* adult equivalent, *EP* edible portions

*Significantly different between locations (rural and urban) $p < 0.5$; **Significantly different between Q5 and Q1 $p < 0.5$ (actual result $p = 0.000$)

[a]All quintiles significantly different within each quintile increase (except two, 2010 Q1 and Q2 milk. 2015 Q1 and Q2 meats)

Fig. 1 Share of ASF groups in total ASF consumption by location, 2010 and 2015 (%)
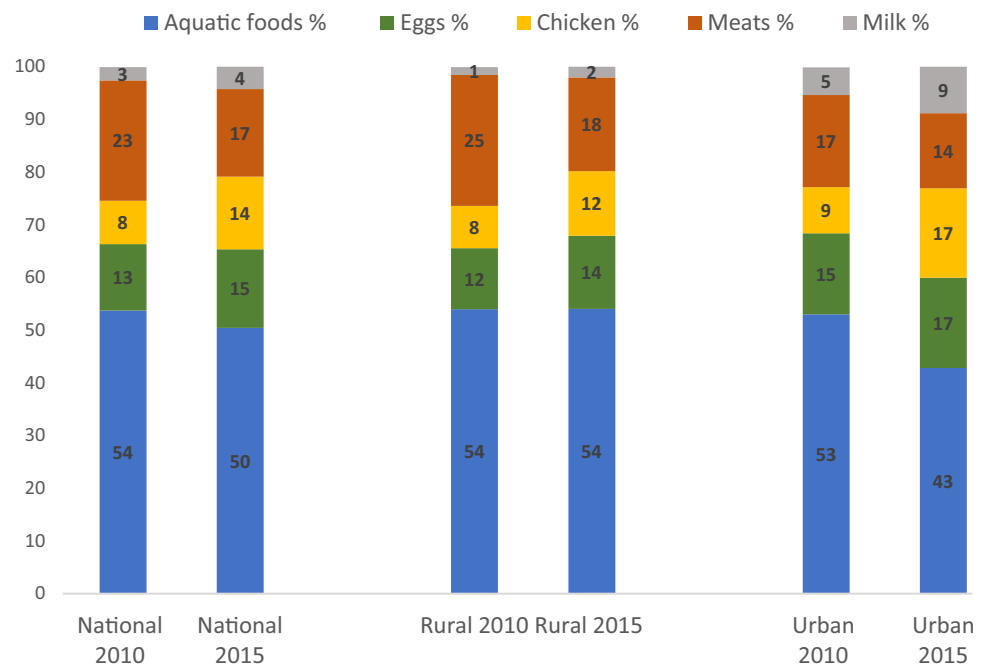
improvement was offset by a large decrease in the consumption of livestock meats.

3.3 Changes in the composition of ASF consumption

The composition of ASF consumed changed markedly from 2010–2015, particularly in urban areas (Fig. 1). Consumption of aquatic foods dropped slightly (-3 g/AE/day) between the two surveys, falling more sharply in urban (-5.5 g/AE/day) than rural (-2.1 g/AE/day) areas. The share of aquatic foods in rural ASF consumption (measured in g/AE/day) remained constant between 2010 and 2015 at 54%, but its contribution in urban areas fell ten percentage points, from 53 to 43%. In 2010, consumption of pork in rural areas was significantly higher than in urban areas (15.9 and 10.9 g/AE/day, respectively), but by 2015, rural pork consumption fell to the same level as urban pork consumption, which remained unchanged since 2010. Consumption of other meats (mainly beef and goat) also fell from 2010 to 2015 (from 9.1 to 6.3 g/AE/day). The combined share of ASF contributed by pork, beef, and goat fell from 25 to 18% for rural consumers and from 17 to 14% for urban consumers between the two survey years.

Increases in urban ASF intakes were driven by a doubling of chicken and milk consumption and a 24% increase in egg consumption. Urban consumption of eggs and chicken rose by 3.9 g and 10.7 g/AE/day, respectively, between the two survey rounds (Table 3). Rural consumption of these foods increased by a much smaller amount (1.8 and 3.8 g/AE/day, respectively). The share of fresh milk in ASF consumption grew from 5 to 9% among urban consumers, from 2010 to 2015, but remained low for rural consumers (rising from 1 to 2%) (Fig. 1).

Temporal changes in the composition of ASF consumed varied across expenditure quintiles (Fig. 2). The poorest consumers were most dependent on aquatic foods in both survey years. Aquatic foods provided 59% of ASF eaten by consumers in Q1 in both 2010 and 2015. In contrast, the importance of aquatic food consumption declined for wealthier consumers, falling from 52% of ASF consumption in 2010 to 45% in 2015 for Q5.

The contribution of pork, beef, and goat to total ASF consumption fell across all expenditure quintiles from 2010 to 2015, but this drop was far greater for poorer consumers (from 22 to 11% in Q1) than the better-off (from 21 to 18% in Q5). The share of chicken in ASF grew rapidly for consumers in all expenditure quintiles (up from 6 to 11% for those in Q1 and from 11 to 16% for those in Q5). However, for the poorest consumers this increase was inadequate to offset the reduction in consumption of other meats, resulting in an overall reduction in the share of meat in total ASF from 28 to 22%. In contrast, higher intakes of chicken more than offset the small decline in other meat for consumers in Q5, causing the share of meat in total ASF consumption to rise from 22 to 34%.

The contribution of eggs to ASF consumption was similar across expenditure quintiles (e.g., 12% for Q1 and 13% for Q5 in 2010) but increased slightly over time (to 15% and 14% for Q1 and Q5, respectively, in 2015). Fresh milk consumption as a share of ASF tended to increase with income, becoming somewhat more important between the two survey years, particularly for consumers in Q4 and Q5.
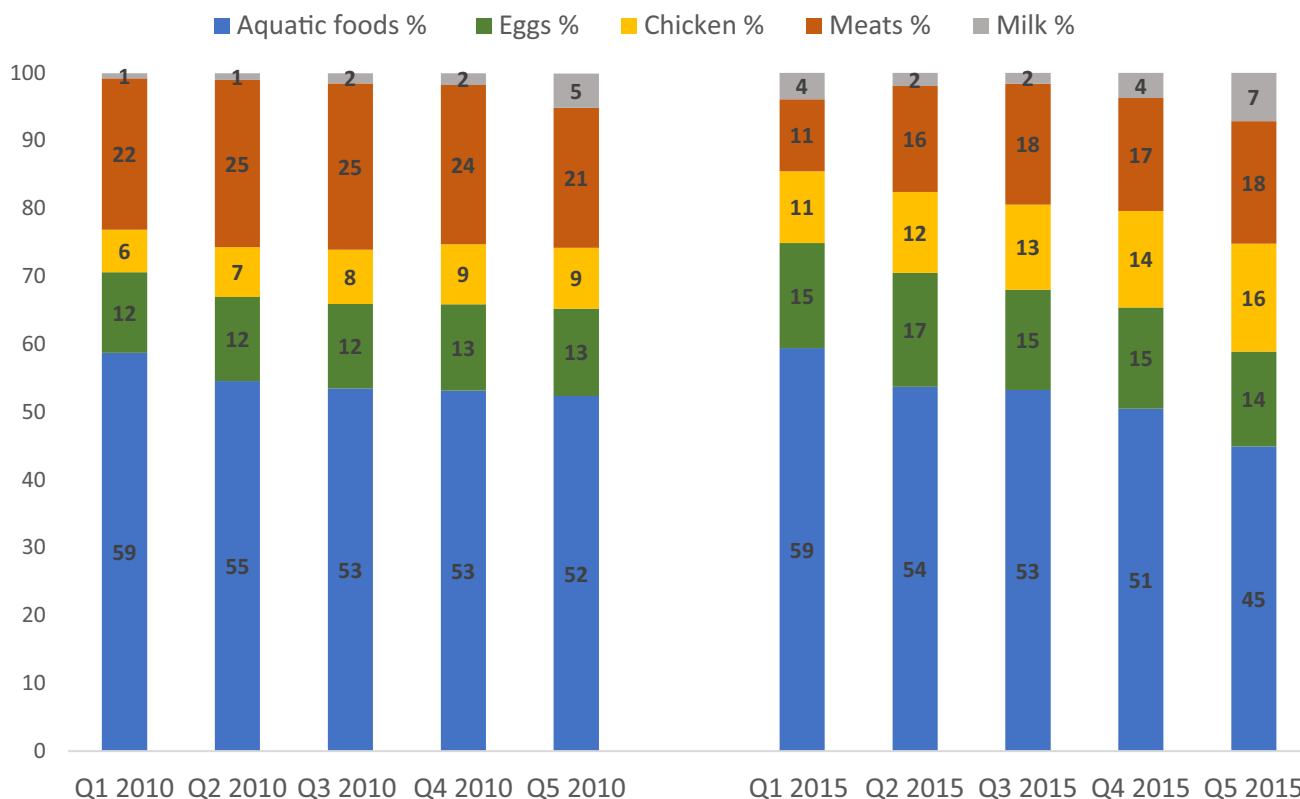
Fig. 2 Share of ASF groups in total ASF consumption by expenditure quintile, 2010 and 2015 (%)

3.4 Estimated intakes of nutrients from ASF

This sub-section extends the preceding analysis of the quantities and composition of ASF consumed, to estimate the contribution of different ASF to requirements of energy, protein and fat; five minerals (sodium, calcium, iron, selenium, zinc) and three vitamins (thiamine, vitamin A, vitamin B12) in 2010 and 2015. Results are presented in Table 4 (see Table 7 in the Annex for estimated average nutrient intakes). Below, we discuss the overall contribution of ASF to EARs and its evolution over time, before evaluating the contributions of different types of ASF to nutrient adequacy. We then examine variations in nutrient adequacy by expenditure quintile.

Table 4 Contributions of ASF to adult EARs (%), 2010 and 2015

	Reference EAR	Aquatic foods (%)		Eggs (%)		Chicken (%)		Pork (%)		Meats (%)		Fresh milk (%)		Total ASF	
		2010	2015	2010	2015	2010	2015	2010	2015	2010	2015	2010	2015	2010	2015
Energy (kcal)	2000	3.3	3.0	1.0	1.2	0.9	1.5	2.7	2.0	1.2	0.9	0.1	0.1	9.2	8.8
Protein (g)	50	23.2	21.7	3.3	3.9	3.1	5.3	4.0	3.0	3.1	2.1	0.2	0.3	36.9	36.3
Fat (g)	50	3.7	3.2	2.9	3.3	2.5	4.3	10.1	7.6	3.7	2.9	0.2	0.3	23.1	21.6
Sodium (mg)	2000	52.3	51.3	0.9	1.1	0.3	0.5	0.3	0.2	0.6	0.5	0.1	0.1	54.5	53.7
Calcium (mg)	860	29.5	26.1	0.9	1.0	0.1	0.2	0.3	0.2	0.1	0.1	0.3	0.6	31.3	28.3
Iron (mg)	20.8	13.2	11.3	1.6	1.8	0.4	0.6	0.5	0.4	0.9	0.6	0.0	0.0	16.6	14.7
Zinc (mg)	6.85	8.1	7.5	2.5	3.0	1.6	2.7	3.3	2.5	6.0	3.6	0.1	0.2	21.8	19.6
Selenium (µg)	45	29.3	32.6	9.4	11.1	2.7	4.6	9.1	6.8	3.3	2.4	0.2	0.4	54.1	57.8
Thiamin (mg)	0.95	1.3	1.3	1.2	1.2	0.5	0.9	9.0	6.8	1.0	0.9	0.1	0.2	13.1	11.3
VitB12 (µg)	2	69.2	63.3	17.1	17.0	1.3	2.2	4.4	3.3	13.7	7.8	0.6	1.0	106.5	94.6
VitA (µg)	530	9.8	9.5	4.2	4.9	0.7	1.1	0.1	0.0	0.1	0.1	0.2	0.4	15.0	16.0

Table 5 Simplified food composition table comparing content of select nutrients per 100 g edible portion obtained from key ASF in Myanmar

Food item	Energy (kcal)	Protein (g)	Fat (g)	Sodium (mg)	Calcium (mg)	Iron (mg)	Zinc (mg)	Selenium (µg)	Thiamin (mg)	VitB12 (µg)	VitA (µg RAE)
Fish, freshwater Rohu	100.96	18.2	3	61	51	0.98	1	29	0.01	5.05	13
Fish, small river, composite	424.33	15.97	4.3	52.33	1033	3.93	2.97	17.00	0.02	5.97	950.33
Fish, dried snakehead	249	45.7	7	2336*	194	3.3	0.28*	83*	0.13*	1.75*	n/a
Eggs (chicken)	143	12.56	9.51	142	56	2.4	1.29	30.7	0.04	0.89	160
Chicken	215	18.6	15.06	70	11	0.9	1.31	14.4	0.06	0.31	41
Pork	376	13.91	35.07	42	19	0.7	1.59	28.4	0.595	0.61	2
Beef	222	19.79	15.06	50	17	1.7	3.97	22.8	0.075	1.61	2
Fresh milk	61	3.15	3.27	43	113	0.0	0.37	3.7	0.046	0.45	46

*Imputed value from matched item

Average energy intakes remained relatively stable from 2010 (2442 kcal) to 2015 (2452 kcal); just over the estimated requirement of 2400 kcal for an average, moderately active adult (Allen et al., 2006). Households in expenditure quintile 1 and 2 fell somewhat below this level in both survey rounds. ASF accounted for a small share of average energy intakes in both years, remaining stable at 7% (see Table 8).

ASF are an important source of multiple micronutrients. National average ASF intakes met > 100% of the vitamin B12 EAR, half of selenium, one-third of calcium, 15–20% of iron, zinc, and vitamin A, and 10% of thiamine. ASF contributed around one-third of protein requirements, less than one-quarter of fat, and 10% of energy. Just over half of the sodium upper limit originated from ASF, primarily processed aquatic foods. Excessive sodium intakes are associated with negative health outcomes.

We found small declines (around 2 percentage points) in the contribution of ASF to nutrient adequacy for five out of eight scarce micronutrients (calcium, iron, zinc, thiamine, vitamin B12) and small increases in two (selenium and vitamin A) in 2015, though due to the differences in the sample design of the two surveys, it was not possible to assess their significance. Given that average intakes of ASF remained stable across survey rounds at 103 g/AE/day (Table 4), this result could suggest that the changing composition of ASF consumed led to slight declines in average dietary quality. There was little change in the contribution of ASF to requirements of energy or protein, or sodium limits.

Considering the contributions of different ASF to nutrient adequacy, we find that aquatic foods make by far the largest contributions to protein and the EARs of calcium, iron, and vitamins: B12 and A (accounting for between 60% and > 90% of EARs from ASF for these nutrients). Aquatic foods also provide more than half of ASF-derived zinc and over one-third of selenium. This pattern is partly attributable to the large quantities of aquatic foods consumed relative to other ASF (54% of the total in both years), but also reflects their high nutrient density relative to most other ASF, particularly when consumed in processed form.

Milk is well recognised as a rich source of calcium (Choudhury & Heady, 2018) but contributes little to EARs of calcium or any other nutrient in Myanmar, due to the very small amounts consumed. Aquatic foods are thus the main source of calcium from ASF in the Myanmar diet (accounting for 92% of the ASF derived calcium in 2015). Calcium in aquatic foods is supplied mainly by items such as small fish, the bones of which are commonly consumed whole, and dried fish and shrimp products. Processed aquatic foods - particularly fish paste and fish sauce, which account for around one-third of aquatic food consumption, supply a large portion of the dietary iron derived from ASF at the national level (Table 9, Annex). Less positively, processed aquatic foods also supply half of the recommended limit for sodium

Table 6 Food consumption expenditure shares by food group, 2010 and 2015

	2010								2015							
	National	Urban	Rural	Q1	Q2	Q3	Q4	Q5	National	Urban	Rural	Q1	Q2	Q3	Q4	Q5
Staples	27	22	29	36	30	26	23	19	24	19	26	35	28	23	20	15
Pulses & nuts	4	4	5	4	5	5	5	4	3	3	4	4	4	4	3	3
Milk	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Eggs	4	4	3	3	4	4	4	4	3	4	3	3	4	3	3	3
Aquatic foods	13	14	12	11	12	13	14	15	13	14	13	11	12	13	13	14
Poultry	6	6	6	4	6	6	7	7	6	8	5	4	5	6	7	8
Other meat	9	7	9	8	9	9	9	8	6	7	6	3	6	7	6	8
Veg. & fruits	16	15	16	15	16	16	16	16	16	17	16	16	16	16	17	17
Oils	6	6	6	6	7	6	6	6	6	5	6	7	6	6	5	5
Sugars & sweets	3	4	2	1	2	2	3	5	4	4	3	2	3	4	4	5
FAFH	7	12	5	4	6	7	8	11	11	14	10	6	9	11	13	16
Others	5	4	6	6	6	5	5	5	7	5	8	8	8	7	6	5
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

due to the addition of salt during processing, suggesting the potential for sodium overconsumption in the total diet.

Eggs are the next most significant contributor to EARs for vitamins B12 and A, and selenium, providing roughly 20–30% of ASF derived EARs for these nutrients in 2015. Pork is most notable for its contributions to fat and energy intakes (one third and one quarter, respectively, of the total from ASF in 2015), and thiamine (60%), though all contributions declined from 2010 to 2015. The contribution of other meats to EARs fell between the two surveys, with the most notable contribution being 18% of ASF-derived zinc in 2015 (down from 28% in 2010). The contribution of chicken to most nutrients nearly doubled over this period, but with the largest increase for fat (from 11 to 20% of the total derived from ASF).

Decreases in the adequacy of intakes of several nutrients between 2010 and 2015, including iron, zinc, and vitamin B12, reflect lower consumption of fish, pork and other meats. Chicken served as a substitute for these foods in terms of quantity but did not fully compensate in terms of micronutrients, due to differences in their nutrient composition. However, small increases in selenium and vitamin A intakes are attributable to combined increases in egg and chicken consumption that more than offset declines from other sources (Table 4).

Figure 3 depicts the contribution of ASF to EARs by wealth quintile. Income linked differences in ASF consumption gave rise to stark inequalities in the contribution of ASF to nutrient adequacy, and very inadequate micronutrient intakes among the poorest groups (Fig. 3). For example, individuals in Q1 consumed well under 20% of their EARs of calcium, iron, zinc, thiamine, and vitamin B12 from ASF. However, consumers in the upper expenditure quintiles clearly benefited from the nutrient contributions of ASF. The

gap in average ASF intakes between consumers in Q1 and Q5 equates to meeting 17% and 59% of protein, 9% and 20% of iron, 19% and 40% of calcium, 4% and 20% of thiamine, and 9% and 33% of zinc requirements, respectively.

However, ASF made substantial contributions to intakes of total fat (38%) (mainly from pork and chicken) and sodium (72%), for members of Q5, possibly warranting moderation in ASF consumption, given the availability of saturated fats and sodium from other components of the diet, in the context of the emerging triple burden of malnutrition and NCDs. On average, consumers in Q5 consume double the dried and processed fish products – a major source of sodium - than those in Q1, in keeping with their much higher consumption of almost all ASF (e.g., 171% more total aquatic foods, 224% more eggs, 467% more pork and 542% more milk).

3.5 Changes in ASF prices

Figure 4 depicts an index of ASF retail prices, collected by the Central Statistical Office on a weekly basis from April 2008 to February 2018 from markets around Myanmar, adjusted for inflation using the general consumer price index. We present this information to provide additional context to the household survey results presented above and analysis in the following section. The following trends are evident. (1) Real prices of eggs and chicken fell steadily and ended the period 36% and 29% cheaper, respectively, than in 2008. (2) The price of the main farmed fish produced in Myanmar, rohu carp, remained relatively stable, particularly in the latter half of the decade, and was 5% cheaper in real terms in 2018 than in 2008. (3) The real price of pork increased more slowly than that of other red meats but ended

Table 7 Mean nutrient intakes (g/AE/day) from ASF, 2010 and 2015

2010	Aquatic foods	SE	Eggs	SE	Chicken	SE	Pork	SE	Meats	SE	Fresh milk	SE	Total ASF	SE	Total ASF % EAR
Energy (kcal)	65.93	(2.28)	20.55	(0.76)	18.18	(0.87)	54.02	(2.38)	23.43	(1.26)	1.57	(0.27)	184.04	(4.37)	9
Protein (g)	11.59	(0.37)	1.63	(0.06)	1.57	(0.08)	2.00	(0.09)	1.55	(0.09)	0.08	(0.01)	18.44	(0.45)	37
Fat (g)	1.85	(0.09)	1.44	(0.06)	1.27	(0.06)	5.04	(0.22)	1.87	(0.10)	0.08	(0.01)	11.57	(0.31)	23
Sodium (mg)	1045.78	(45.72)	18.50	(0.66)	5.92	(0.28)	6.03	(0.27)	12.40	(1.34)	1.11	(0.19)	1090.00	(45.26)	55
Calcium (mg)	253.73	(8.40)	7.62	(0.28)	0.93	(0.04)	2.73	(0.12)	0.92	(0.05)	2.91	(0.50)	269.50	(8.52)	31
Iron (mg)	2.76	(0.09)	0.33	(0.01)	0.08	(0.00)	0.10	(0.00)	0.18	(0.01)	0.00	(0.00)	3.45	(0.10)	17
Zinc (mg)	0.56	(0.01)	0.17	(0.01)	0.11	(0.01)	0.23	(0.01)	0.41	(0.03)	0.01	(0.00)	1.49	(0.03)	22
Selenium (µg)	13.17	(0.57)	4.24	(0.15)	1.22	(0.06)	4.08	(0.18)	1.51	(0.09)	0.10	(0.02)	24.33	(0.68)	54
Thiamin (mg)	0.01	(0.00)	0.01	(0.00)	0.01	(0.00)	0.09	(0.00)	0.01	(0.00)	0.00	(0.00)	0.12	(0.00)	13
VitB12 (µg)	1.38	(0.05)	0.34	(0.02)	0.03	(0.02)	0.09	(0.00)	0.27	(0.02)	0.01	(0.00)	2.13	(0.06)	106
VitA (µg)	51.77	(3.27)	22.33	(0.82)	3.47	(0.17)	0.29	(0.01)	0.34	(0.05)	1.19	(0.21)	79.56	(3.22)	15

2015	Aquatic foods	SE	Eggs	SE	Chicken	SE	Pork	SE	Meats	SE	Fresh milk	SE	Total ASF	SE	Total ASF % EAR
Energy (kcal)	60.39	(1.76)	23.89	(0.62)	30.57	(1.00)	40.72	(2.05)	17.59	(1.80)	2.65	(0.28)	175.82	(4.36)	9
Protein (g)	10.86	(0.30)	1.94	(0.05)	2.64	(0.09)	1.51	(0.08)	1.05	(0.09)	0.14	(0.01)	18.14	(0.41)	36
Fat (g)	1.61	(0.07)	1.65	(0.04)	2.14	(0.07)	3.80	(0.19)	1.46	(0.16)	0.14	(0.02)	10.80	(0.32)	22
Sodium (mg)	1025.36	(37.38)	22.02	(0.55)	9.95	(0.32)	4.55	(0.23)	10.04	(1.34)	1.87	(0.20)	1073.78	(37.84)	54
Calcium (mg)	224.84	(6.95)	8.98	(0.23)	1.56	(0.05)	2.06	(0.10)	0.67	(0.07)	4.91	(0.52)	243.02	(7.07)	28
Iron (mg)	2.35	(0.08)	0.37	(0.01)	0.13	(0.00)	0.07	(0.00)	0.13	(0.01)	0.00	(0.00)	3.05	(0.09)	15
Zinc (mg)	0.51	(0.01)	0.20	(0.01)	0.19	(0.01)	0.17	(0.01)	0.25	(0.02)	0.02	(0.00)	1.34	(0.03)	20
Selenium (µg)	14.66	(0.47)	4.98	(0.13)	2.05	(0.07)	3.08	(0.16)	1.06	(0.10)	0.16	(0.02)	25.99	(0.60)	58
Thiamin (mg)	0.01	(0.00)	0.01	(0.00)	0.01	(0.00)	0.06	(0.00)	0.01	(0.00)	0.00	(0.00)	0.11	(0.00)	11
VitB12 (µg)	1.27	(0.04)	0.34	(0.01)	0.04	(0.00)	0.07	(0.00)	0.16	(0.01)	0.02	(0.00)	1.89	(0.05)	95
VitA (µg)	50.17	(3.27)	26.12	(0.67)	5.83	(0.19)	0.22	(0.01)	0.66	(0.16)	2.00	(0.21)	84.99	(3.52)	16

Table 8 Mean energy intakes by food group (Kcal/AE/day)

	2010							
	National	**Urban**	**Rural**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Staples	1659	1265	1798	1558	1659	1702	1752	1625
Pulses & seeds	134	121	138	71	108	136	162	191
ASF	163	154	166	89	132	162	194	238
Veg & fruits	92	87	94	55	78	92	110	128
Others	404	460	385	221	323	393	477	608
Total	2452	2086	2581	1994	2300	2485	2694	2790
	2015							
Staples	1474	1110	1614	1389	1533	1509	1531	1411
Pulses & seeds	110	92	117	64	97	106	139	144
ASF	158	174	152	67	112	151	194	268
Veg & fruits	86	92	84	47	64	83	104	132
Others	614	613	614	337	490	634	751	857
Total	2442	2080	2581	1904	2296	2483	2719	2811

the period up 10% in real terms. (4) Beef and mutton prices followed very similar trends and are presented as a combined average price index here. Real beef/mutton prices increased sharply, especially after 2012, ending 34% higher in 2018 than in 2008. (5) Fish from capture fisheries (an average of the prices of hilsa, snakehead, stinging catfish, and walking catfish) experienced the steepest price increases, ending around 50% higher in real terms in 2018 than 2008.

Table 9 Disaggregated contribution of aquatic foods to mean nutrient consumption (AE/day) and EAR (%)

2010	**Freshwater**		**Marine**		**Processed products**	
	Nutrient/AE/day	% EAR	Nutrient/AE/day	% EAR	Nutrient/AE/day	%EAR
Energy (kcal)	30.2	1.5	6.2	0.3	29.5	1.5
Protein (g)	4.9	9.9	1.1	2.2	5.5	11.1
Fat (g)	1.1	2.2	0.2	0.3	0.6	1.2
Sodium (mg)	17.6	0.9	8.7	0.4	1019.5	51.0
Calcium (mg)	106.8	12.4	8.1	0.9	138.8	16.1
Iron (mg)	0.5	2.2	0.1	0.3	2.2	10.7
Zinc (mg)	0.4	5.1	0.1	1.0	0.1	2.1
Selenium (µg)	7.0	15.5	2.0	4.4	4.2	9.4
Thiamin (mg)	0.0	0.6	0.0	0.2	0.0	0.5
VitB12 (µg)	1.1	55.3	0.1	7.4	0.1	6.6
VitA (µg)	44.7	8.4	2.7	0.5	4.4	0.8
2015	**Freshwater**		**Marine**		**Processed products**	
National	Nutrient/AE/day	% EAR	Nutrient/AE/day	% EAR	Nutrient/AE/day	%EAR
Energy (kcal)	25.1	1.3	8.2	0.4	27.1	1.4
Protein (g)	4.2	8.5	1.5	3.0	5.1	10.2
Fat (g)	0.9	1.8	0.2	0.4	0.5	1.1
Sodium (mg)	12.0	0.6	11.5	0.6	1001.9	50.1
Calcium (mg)	93.9	10.9	14.8	1.7	116.1	13.5
Iron (mg)	0.4	1.9	0.1	0.4	1.9	9.0
Zinc (mg)	0.3	4.5	0.1	1.0	0.1	2.0
Selenium (µg)	6.0	13.2	3.5	7.7	5.2	11.6
Thiamin (mg)	0.0	0.5	0.0	0.3	0.0	0.5
VitB12 (µg)	0.9	47.2	0.2	8.1	0.2	8.0
VitA (µg)	43.3	8.2	2.5	0.5	4.4	0.8
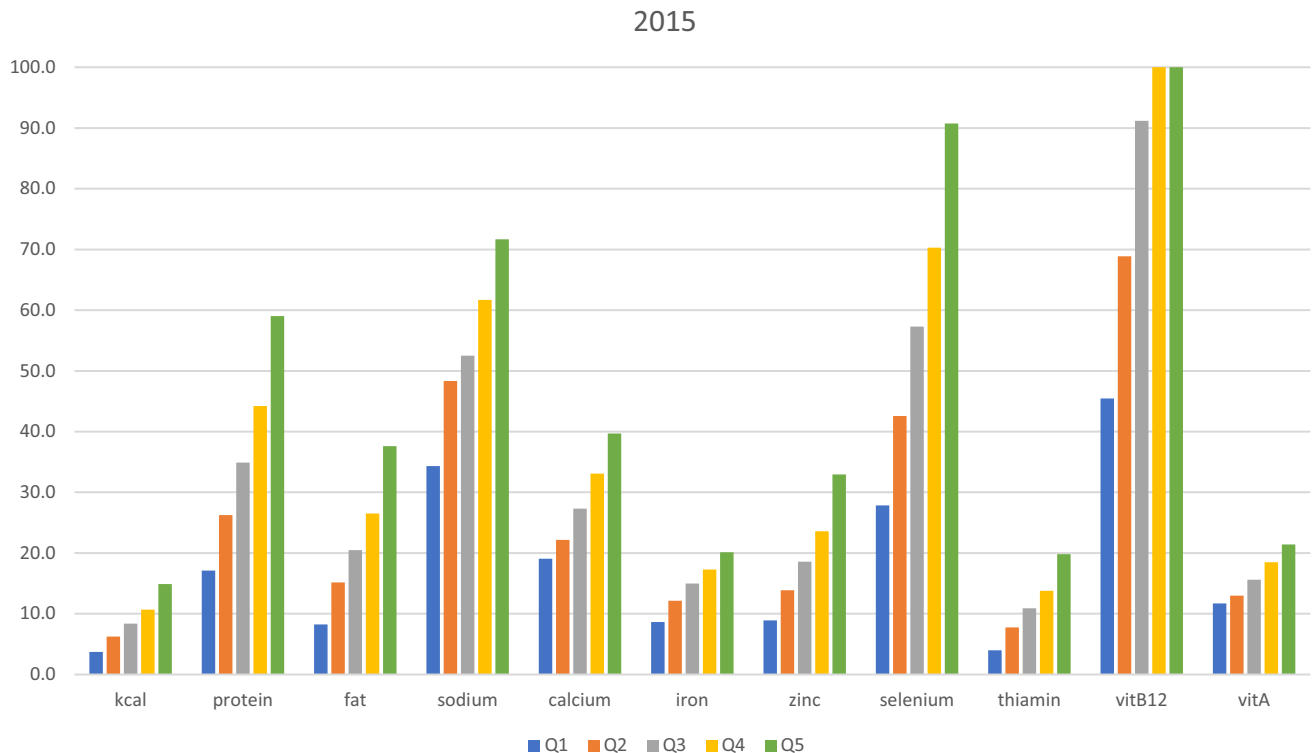
Fig. 3 Mean contribution (%) of ASF intake to adult nutritional EAR by expenditure quintile, 2015. *Vitamin B12 intakes exceed 100% EAR for Q4 (114% EAR) and Q5 (153% EAR)

4 Discussion

This study links the growing literature on the role of ASF in supporting human nutrition in the Global South (Adesogan et al., 2020; Headey et al., 2018; Miller et al., 2022; Zaharia et al., 2021), to the literature on diet transformation and the emergence of the triple burden of malnutrition (e.g., Popkin & Ng., 2022; Reardon et al., 2014; Tschirley et al., 2015). In the preceding sections, we traced changes in consumption of ASF and calculated their contributions to estimated requirements of key nutrients in Myanmar, from 2010 and 2015, spanning a period of rapid economic change. In this section, we review the paper's methodological contributions, synthesize key results and link the trends revealed to changes in Myanmar's economy and food system.

4.1 Methodological contributions

Methodologically, the study combines food consumption data from two nationally representative household surveys with food composition data compiled from multiple databases to estimate levels of consumption of ASF-derived micronutrients in Myanmar, at two intervals, 2010 and 2015, during a period of rapid economic and social change. This approach is not intended as a replacement for the 'gold standard' of individual dietary measures.

Rather it is an alternative method, capable of providing valuable insights into changing patterns of nutrient adequacy in LMIC settings where individual dietary measures data are generally unavailable but national-scale household living standards measurement surveys (LSMS) are common (Fiedler et al., 2012).

Myanmar's ILCHA and MPLCS datasets have an unusually high level of disaggregation in the categories of aquatic foods recorded, totalling 37 items in 2015. The micronutrient profiles of aquatic foods are highly variable (Bogard et al., 2015). This high level of granularity permitted a much higher degree confidence in the estimation of ASF derived micronutrient intakes than if the survey instrument had collected data on one or a small number of categories of aquatic foods; a more common scenario in LSMS style surveys (c.f. Liverpool-Tasie et al., 2021). As such, the design of Myanmar's national household survey consumption modules offers an example of best practice for other countries to emulate in contexts where aquatic species constitute an important component of people's diets.

To maximize the value of such data to researchers, national household survey food consumption modules should include the most common aquatic foods consumed in a given country, ideally reported in ways that make it possible to distinguish between fish originating from capture fisheries and aquaculture (Naylor et al., 2021). Even in
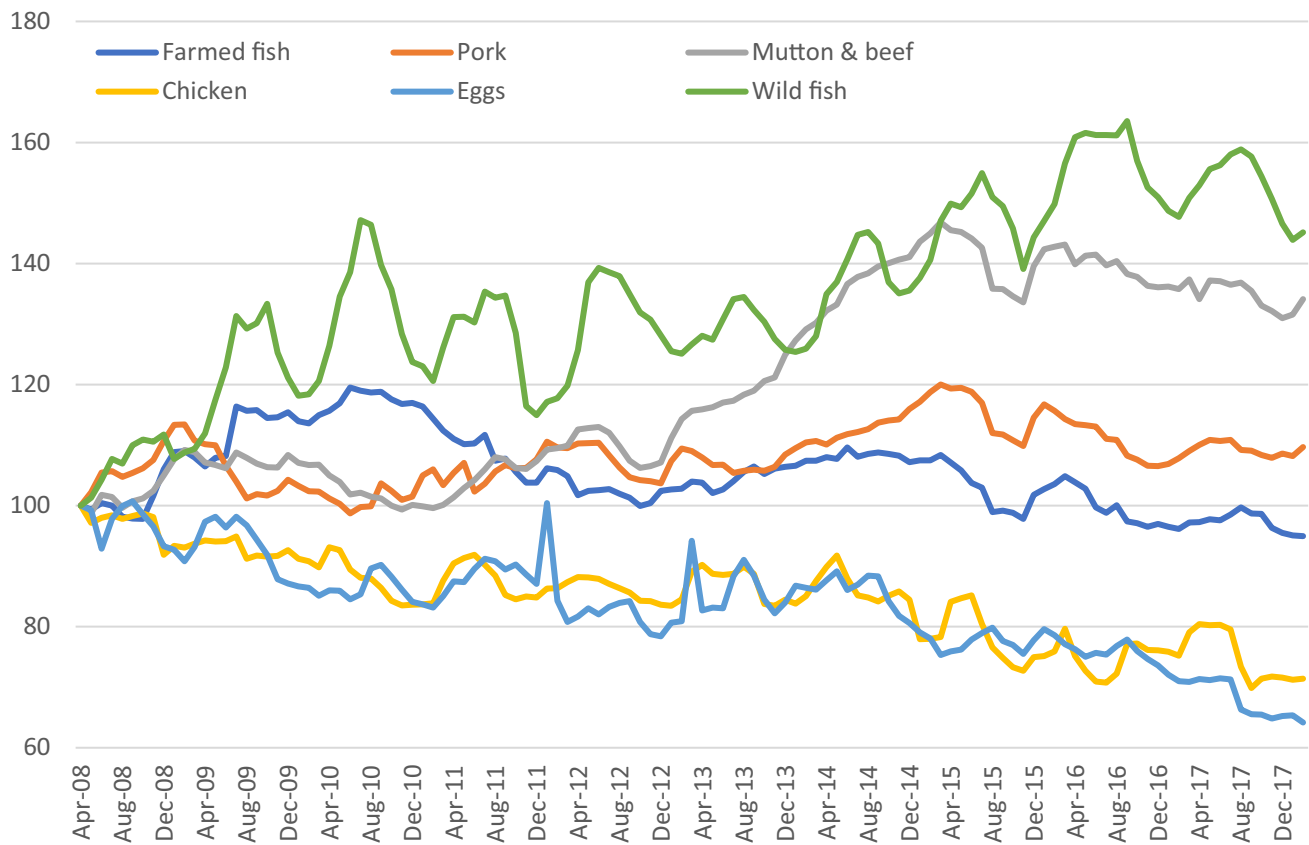
Fig. 4 Index of real retail prices of selected ASF in Myanmar, April 2008 to February 2018 (Source: Author calculations from consumer price index data published in CSO Monthly economic indicators (2008–2017)

locations with high levels fish consumption, most households will consume a limited number of different aquatic foods within a seven-day survey recall period, making it possible to collect this information without significantly increasing survey implementation time and costs.

4.2 Empirical contributions

The methods outlined above allow us to infer that ASF make a vital contribution to the food and nutrient requirements of Myanmar's population. Most dietary energy and protein in the Myanmar diet are obtained from rice, which is consumed in large quantities, averaging 156 kg/capita/year (Dorosh et al., 2019). ASF are among the densest sources of many micronutrients, in their most bioavailable forms, suggesting a high likelihood of widespread undernutrition, as nutrients originating from other foods in the diet are unlikely to be sufficient to make up shortfalls in nutrient EARs. Studies indicating that diet diversity and intakes of other nutrient dense foods (e.g. vegetables, legumes, nuts) are inadequate to meet total dietary requirements support this inference (MoHS, 2017). Together these factors result in high levels of micronutrient

deficiencies in the population, as confirmed by the high rates of stunting, anaemia and other indicators of undernutrition reported in numerous health surveys; e.g. Myanmar Micronutrient survey (MoHS, 2017; Mahrt et al., 2023) and Demographic Health Survey (MoHS & ICF, 2017).

Although average total ASF consumption per AE remained stable nationally between 2010 and 2015, the composition of those ASF changed substantially between survey rounds. Aquatic foods are the most important group of ASF eaten in Myanmar in terms of quantities consumed and the share of most micronutrients supplied. This pattern is consistent irrespective of rural/urban location or expenditure quintile. The poorest consumers are disproportionately more reliant on aquatic foods for ASF and nutrient intakes. However, average quantities of aquatic foods eaten declined slightly over survey rounds, and at a faster rate in urban areas than in rural. Per capita consumption of beef, mutton and pork also declined between survey rounds, to an even greater extent than consumption of aquatic foods.

In urban areas, a steep rise in chicken consumption and growing consumption of eggs and milk were sufficient to more than offset declines in the quantity of meats and aquatic foods eaten during the period in question. In rural

areas consumption of chicken, eggs, and dairy increased more slowly. Although better-off (mainly urban) consumers increased their consumption of ASF between the two survey rounds, the quantity of ASF eaten by the poorest (mainly rural) consumers fell somewhat from 2010 to 2015, resulting in widening nutrition inequality. Consumers in expenditure quintile 5 consumed 124 g/day more ASF in 2015 than those in quintile 1 on average, equating to 1 – 2 more servings of ASF per day (Uyar et al., 2021).

The changing composition of ASF, toward lower quantities of diverse nutrient-dense aquatic foods and red meat, but higher quantities of less nutritious chicken, resulted in small reductions in the contributions of ASF to EARs of several key micronutrients. This trend is of particular concern given that consumption of micronutrients derived from ASF by poorer households is severely inadequate. In contrast, levels of ASF eaten by better-off households may tip into excessive consumption.

The widening rural/urban and low income/high income divide in ASF consumption occurred during a period of rapid economic growth. The gap in average chicken consumption among consumers in quintiles 1 and 5 nearly doubled from 2010–2015, a period during which average GDP growth exceeded 7% (World Bank, 2019) and intensive chicken farming expanded rapidly (Belton et al., 2020). Together, these trends seem to imply that increased supply of chicken did not result in pro-poor effects on consumption during this period. This pattern could suggest that the distribution of rising incomes associated with growth needs to be pro-poor if access to ASF is also to be pro-poor; a scenario that was observed in Bangladesh from 2000 to 2010, when rapidly rising rural incomes enabled poorer consumers to increase their consumption of farmed fish at a faster rate than the non-poor (Toufique & Belton, 2014).

For the wealthiest quintile, intakes of fat (38% of EAR) and sodium (72%) from ASF are elevated, flagging a potential tipping point into excess ASF intakes, and may contribute to adverse health outcomes, in combination with other sources of saturated and trans fat and salt in the diet. This could signal a negative nutrition transition towards more 'Western' patterns of high meat intake, as observed in other Southeast Asian countries including Thailand (Smitasiri et al., 1999), and Vietnam (Raneri et al., 2019).

These findings suggest that a nutrition transition has begun in Myanmar, similar to many other LMICs, where higher incomes and urbanization are associated with higher consumption of ASF and other nutrient-dense foods such as fruit and some vegetables, as well as higher energy, protein and saturated fat intakes (Mayén et al., 2014). However, intakes of some micronutrients may remain inadequate even among better-off consumers, despite potentially excessive intakes of sodium and fat. Moderating consumption of ASF thus has the potential to increase some micronutrient deficiencies. Dried aquatic foods require an average of 4 kg of raw produce to make 1 kg of dried product, resulting in a highly concentrated source of nutrients (Liverpool-Tasie et al., 2021). Given that most sodium intake from ASF originates from processed foods such as dried and fermented fish, identifying processing methods that minimize sodium levels may offer potential to reduce nutrition trade-offs.

Rising consumption of chicken and eggs between 2010 and 2015 reflects the rapid growth of intensive commercial broiler and layer farming that increased the supply of poultry and eggs. For example, the number of chicken farms surrounding Yangon doubled in just five years between 2014 and 2018 (Belton et al., 2020). Commercial-scale intensified pig farming also began to grow in peri-urban areas after 2010, but from a lower base and expanding more slowly than poultry farming (Belton et al., 2020).

Data limitations meant that it was not possible for us to distinguish between aquatic foods originating from capture fisheries and aquaculture, but landings from Myanmar's freshwater and marine capture fisheries are known to have declined sharply over the past decade (Hosch et al., 2021), while aquaculture has expanded relatively quickly, changing the diversity and composition of aquatic foods consumed, particularly in urban areas (Tezzo et al., 2021). It is also possible that the expansion of feed milling industries in Myanmar servicing more intensive forms of livestock and animal production and utilizing fishmeal as an ingredient may have diverted small marine fish from human food chains, but further research is needed to test this hypothesis.

Changes in supply and relative prices appear to have contributed to substitution of chicken and eggs for red meats, substitution of farmed fish for fish from capture fisheries and, to a smaller extent, substitution of chicken and eggs for aquatic foods. Similar patterns have been observed in Bangladesh, where diverse but increasingly scarce and expensive fish from inland capture fisheries have been replaced by cheaper but less nutrient-dense farmed fish, leading to lower intakes of some micronutrients despite higher levels of fish consumption overall (Bogard et al., 2017). Likewise, in the Peruvian Amazon, farmed fish and chicken have increasingly substituted for diverse species from inland capture fisheries, reducing intakes of iron and essential fatty acids, though zinc and protein intakes increased with chicken consumption (Heilpern et al., 2021).

This study therefore adds to a small but growing body of evidence that farmed fish and chicken are imperfect substitutes for more diverse aquatic foods originating from capture fisheries with respect to diet quality. This observation underscores the importance of managing capture fisheries sustainably to maintain their important contributions to food and nutrition security over the long term. The limited extent of nutrition-sensitive policies focussing on capture fisheries and aquaculture continues

to represent a missed opportunity for sustainable healthy diets (Ahern et al., 2021; Thilsted et al., 2016).

Per our results, the economically dynamic period covered by this study (2010–2015), appears to have been a missed opportunity to improve the nutritional status for those experiencing the greatest burdens of poverty and malnutrition. Today, Myanmar is experiencing protracted crisis, resulting in an estimated national poverty rate of about 50% (MAPSA, 2022; Diao & Mahrt, 2020); double that in 2017 and similar to 2005 levels, five years before the first of the surveys analyzed here was conducted.

This extreme income shock combined with extensive supply side disruptions has resulted in decreased production of ASF (Fang et al., 2021 and Hoong et al., 2021). Consumption of ASF has likely also fallen significantly, given that most ASF are highly income and price elastic in Myanmar (Aung et al., 2022). Such a dietary shift would have lowered ASF-derived micronutrient intakes, reducing already low levels of nutrient adequacy, especially among the most vulnerable population subgroups.

This interdisciplinary research provides evidence to inform policy across multiple sectors, including agriculture, health, and social protection. The findings highlight the importance of double-duty approaches (addressing both under- and over-nutrition) that tailor dietary interventions and policies to specific population sub-groups. The unique role of ASF, and particularly aquatic foods, including in their processed forms, may be leveraged through food-based dietary guidelines (FBDG) and interventions to address malnutrition. This will require increasing consumption and ensuring access (affordability) for vulnerable groups, leveraging micronutrient dence species and products, while simultaneously preventing overconsumption for better-off people.

Studies such as the present one can be used to inform the development of FBDG that more closely reflect cultural preferences. The development of quantified guidelines for ASF consumption that reflect dietary needs, environmental sustainability and sociocultural factors requires global attention (Herforth et al., 2019). Targeted double-duty approaches that aim to increase the diversity of foods in diets with moderate ASF intakes, together with optimising the consumption of diverse nutrient-dense plant-based foods can help to leverage ASF to improve malnutrition and health, and contribute to healthy, sustainable, and ethical diets (Leroy et al., 2022).

5 Conclusion

Our study indicates that inequality in the food system in Myanmar contributed to and intensified an emergent negative nutrition transition, during a brief period of rapid economic growth. ASF consumption and nutrient provision were inequitable for all categories of ASF, and intakes of critical nutrients in the diet were likely highly inadequate, particularly for those in the lower expenditure quintiles, who also experienced the worst rates of micronutrient deficiencies, stunting and undernutrition.

Food and nutrition security in Myanmar has almost certainly been undermined further since 2020 (Mahrt et al., 2023). Ensuring access and availability of diverse, safe nutrient-dense foods, perhaps through the diversification of humanitarian food aid to include culturally appropriate nutrient-dense ASF such as dried fish, may have an important immediate role to play in addressing malnutrition during times of crisis such as these. In the longer term, multisectoral policies are necessary to address shortcomings in the current food system, given its complexity. More interdisciplinary evidence is needed to inform integrated public policies across health, agriculture, and social welfare if the goal of equitable global food system transformation for human and planetary health is to be realised.

Annex

Declarations

Ethics Analyses in this paper are derived from secondary data; primarily from the Government of Myanmar's two most recent nation-wide household expenditure and living standards surveys that are publicly available. Ethics process included - /re original survey.

Conflict of Interest The authors have no conflict of interest to disclose for the manuscript.

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