Future fish supply demand and market trends in Nigeria

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1. Introduction

Being an important part of African agri-food systems, fish has significant role in achieving the goal of food and nutrition security. Nigeria is the largest aquaculture producer in sub-Saharan Africa, second only to Egypt in the whole of Africa. Still, Nigerian capture fisheries continue to dominate about three fourth of total fish production in 2018. Despite the large production levels, local production has continuously struggled to meet domestic demand. Nigeria's self-sufficiency in fish production is declining since the past five decades, showing that fish demand is inversely proportional to domestic fish production. This is reasonable given that Nigeria is the most populous country in Africa, home to nearly 196 million people in 2018. Poverty is one of the root causes of food insecurity. In 2009, more than half of the Nigerian lives below poverty line (US$1.90 per day). Thus, fish play critical role in addressing food and nutrition security. Nigerian relies heavily on fish for food and protein, accounted for 43% animal protein in their diet. It is the largest fish consumer of Africa, with over 2.3 million tonnes being consumed in 2013. In order to fill this demand-supply gap, colossal amounts of fish imports need to be brought in; more than 1 million tonne in 2013. This gap will likely have adverse impact on the diets and nutrition of many vulnerable groups, and can only be bridged by increasing the growth rate of aquaculture and/or by increasing fish imports. Currently Nigeria's existing economic recession and the weak currency (Naira) do not appear to be conducive for increasing fish imports in an economically viable manner. Thus, understanding the dynamics of fish production, consumption, trade, prices, and their implications on food and nutrition security in Nigeria are critical to support national policy and decision-making for ensuring sustained fish production growth while minimizing unexpected socioeconomic and environmental impacts.

The objective of this study was to provide a future macro picture of the fish sector in Nigeria until **2030** and **2050** by projecting the dynamics of fish supply and demand and draw policy implications that can be of interest for policy makers in Nigeria. Specifically, the study aims to produce the following output: *An analysis of Nigeria fish demand, supply and market trends.*

The key research questions that the study seeks to address are:

1. How do capture fisheries and aquaculture production systems in Nigeria respond to the increasing fish demand in the future, considering complex interactions of domestic supply, demand, trade and imports?
2. What are the driving factors that will influence future fish supply, demand and trade?
3. What are the impacts of fluctuating (especially increasing) input costs, (feed, seed, labour, etc.) on aquaculture production in Nigeria?
4. What is the future impact of climate change on aquaculture and capture fisheries production by 2050?
5. How future fish demand and supply will influence future fish markets and what are the investment options and strategies that could improve/increase fish supply and availability to increase the fish sector contribution of fish to Nigerian food and nutrition security?

2. Material and methods

There are a number of models that have been developed to project fish supply and demand, e.g., the fish IMPACT model and the Aglink–Cosimo model(FAO, 2016)(FAO, 2016)(FAO, 2016)(FAO, 2016)(FAO, 2016)(FAO, 2016)(FAO, 2016) - both used to project the global fish sector in medium term. With a focus on the global scale, these models however lack the disaggregation level which is often needed to analyse the fish sector at national level. Other developed models, e.g. the AsiaFish model could provide more disaggregated projection, but they require a large number of parameters to be estimated from real-life data using econometric techniques. This requirement is not possible in the case of Nigeria due to the lack of reliable and quality data. Disaggregated data about the fish sector of Nigeria often exhibit inconsistencies if double-checked from various sources.

To overcome this challenge, our approach was to develop a foresight model which minimizes the level of data-demanding while maintaining the key objective of being able to analyse the key scenarios and evaluate policy impacts on the Nigeria's fish sector. To do so, we limited the analysis to main fish species groups and production types, collected the best reliable information, and then adjusted the modelling specification to fit with what is available.

Our model draws from some previous frameworks. For example, following Dey et al. (2005) and Rosegrant and Team (2012), our model has a multi-species-multi-sector-multi-region equilibrium feature which characterizes the equilibrium of supply and demand on all related markets. This feature allows us to project the outcome in Nigeria's fish sector at a species disaggregation level.

We also adopt a number of modifications in the model structure to enhance its practicality and applicability, given the available data and information. On the supply side in particular, while the ASIA-FISH model specifies fish supply functions by combining the Hotelling's lemma and the estimate of profit function (Dey et al., 2005, see eq. 2), our model specifies how fish supply responds to profit, similar to the global IMPACT model, to best fit with the data availability.

On the consumption side, we also apply a slightly different modeling approach to fit with available data. Here, on the one hand, the IMPACT model specifies iso-elasticity demand functions (Robinson, 2015:17) – a simplistic version of what suggested by consumer theory; and on the other, the ASIA-FISH model uses the AIDS-style demand functions which is consistent with the consumer theory but data-demanding. As a compromise, we specify consumer preference in a basic functional form, which is consistent with theory, and derive the Marshallian demand for each fish species group. With this approach, we can minimize the need for borrowing too many parameters from literature where most of them were not estimated for Nigeria.

2.1 Data

We collaborate with Federal Department of fisheries from Ministry of Agriculture and Rural Development Nigeria to collect and compare data from various sources (Nigeria national statistics from Federal Department of fisheries, FishStatJ, FAOSTAT, UN Comtrade, World Bank LSMS, etc), cross-check and adjust to eliminate inconsistencies. The Nigerian fish production data for year 2015 and Nutrient content by fish group in West Africa in 2012 are listed in Table 1 and 2. Analyze from the Nigeria Living Standards Measurement Study (LSMS) 2015-2016 consumption dataset and UN urban/rural dataset, table 3 summarizes the per capita fish consumption and fish prices across regions. the The model covers seven fish groups, which are referred to by their local names, i.e., Tilapia, Catfish, Carp, Nile Perch (and snakeheads), Clupeids, Shrimp (or prawns), and others. We use a seven-element set to refer to the seven fish group, i.e., $S = [Tilapia, Catfish, Carp, Nile, Clupeids, Shrimp, Others]$. The species included each group, including their scientific names, are detailed in Appendix 1.

Table 1. Nigerian fish production in 2015

Production type	Fish group	Output		Input cost (million US$)				
		Quantity (thousand tonnes)	Value (million US$)	Labour	Seed	Feed	Energy	Others
Large scale aquaculture	Tilapia	7	20	0.4	0.4	15.2	0.2	0.2
	Catfish	34.5	109.2	2.2	3.1	48.1	3.6	2.3
Small scale aquaculture	Tilapia	21	54.6	11.2	1.6	23	2	1.3
	Catfish	168	532.6	88.9	18.8	227.9	15.8	12.1
	Carp	28	72.8	14.9	3.1	32.1	2.6	1.7
	Nile perch & snakehead	19.8	48.7	10.4	1.5	22.6	1.9	1.1
	Others	37.3	81.7	19.7	3.5	42.6	3.5	1.9
Catch artisanal coastal	Catfish	15.3	38.8	6.9			6.9	13.9
	Clupeids	50.7	158.1	26.1			26.1	52.2
	Shrimps	19.4	80.8	14.4			14.4	28.8
	Others	296.3	519.7	93.4			93.4	186.7
Catch artisanal inland	Tilapia	57.4	122.3	20.2			6.1	40.4
	Catfish	94.3	239.3	39.5			12	79
	Carp	15.4	32	5.3			1.6	10.6
	Nile perch & snakehead	21	41.3	6.8			2.1	13.6
	Clupeids	13.8	24.3	4			1.2	8
	Others	135.9	238.3	39.3			11.9	78.6
Catch commercial	Catfish	0.8	2.2	0.1			0.9	0.1
	Shrimps	5.3	41	2.1			16.4	2.1
	Others	10.9	42.4	2.2			17.6	2.2

Table 2. Analysis of nutrient content by fish group

	Unit for 1kg edible portion	Tilapia	Catfish	African carps	Nile perch & snakehead	Clupeids	Shrimps	Other fish
Edible portion		0.65	0.46	0.54	0.61	0.76	0.57	0.60
Protein	g	183.2	175.7	164.5	196.5	192.5	192.8	185.5
Calcium	mg	145.7	234.6	285.0	890.0	900.0	592.1	615.9
Iron	mg	7.9	6.3	9.0	7.0	24.5	13.8	10.6
Zinc	mg	4.4	8.7	12.7	11.0	16.6	14.3	9.7
Iodine	µg	47.9	24.0	n.a.	n.a.	n.a.	490.9	146.7
Vitamin A	µg	10.0	100.8	50.0	60.0	167.5	156.1	116.4
Vitamin E	mg	8.1	2.2	3.5	19.0	6.5	19.3	6.5
Vitamin B6	mg	2.1	2.5	1.7	1.2	5.5	1.1	2.9
Folate	µg	132.0	136.0	145.0	50.0	65.0	135.0	99.2
Vitamin B12	µg	13.1	35.0	17.0	19.0	58.0	21.4	27.7
Monounsaturated fatty acids	g	5.6	9.7	n.a.	n.a.	n.a.	1.7	9.7
Polyunsaturated fatty acids	g	6.2	12.8	n.a.	n.a.	n.a.	3.9	12.8

Data source: 2012 FAO West African Food Consumption Table

Table 3. Summary of regional per-capita fish consumption and fish prices

Region	Quantity (kg/person/year)	Value (US$/person/year)	Average price (US$/kg)
North Rural	5.5	12.9	2.35
North Urban	7.1	19.0	2.69
South Rural	17.1	64.3	3.76
South Urban	16.1	63.7	3.95

2.2 Model Specification

Fish can be produced by either aquaculture and capture fisheries. Aquaculture is further classified into small-scale or large-scale based on the classification criteria used by Ayinla (2007). These classification criteria are summarised in Appendix 2. Wild-catch is also further classified into the artisanal coastal catch, artisanal inland catch and commercial catch following the classification by Akintola and Fakoya (2017). In total, there are five production categories, and we use a five-element set to refer to these categories, i.e., $PC = [SmallAqua, LargeAqua, CoastalArtisanal, Inland\ Artisanal, Commercial]$. The first two elements are aquaculture, and the last three elements are capture fisheries.

Combining the five production categories and the seven fish groups results in 35 combinations of category-groups. Each of these 35 combinations is termed a ‘ production sector’. Not all production sectors are active, or in other words, not all species are produced in all production categories. To distinguish active and non-active sectors, 35 binary variables

$\nu(PC, S)$ were used, one for each sector, to indicate whether the sector is active (value 1) or inactive (value 0).

The production sectors possibly use different sets of inputs. The two aquaculture sectors use five inputs namely labor, feed, seed, energy, and other inputs. Wild-catch sectors only use three inputs, i.e., labor, energy, and others. Fish producers, either aquaculture or wild-catch, earn revenue from selling their fish products and pay the cost of inputs. The profit of fish producers is the difference between the revenue and the cost. Equivalently, the profitability can be calculated via the rate of return, or the benefit-cost ratio (BCR), which shows, on average, how much revenue fish producers can earn for each dollar of cost.

Fish can be consumed domestically or exported. Fish consumers can consume domestically produced or imported products. The model takes into account possible differences in fish consumption between the northern and southern parts of the countries (referred to the North and the South). Appendix 3 lists the states in the North and the South. In each region, the model also controls for the difference between urban and rural areas. Thus, the model includes four regional fish consumers, namely rural north, urban north, rural south, and urban south. We use a four-element set to refer to the regions, i.e., $R = [RuralNorth, UrbanNorth, RuralSouth, UrbanSouth]$.

2.2.1 Production and production inputs

As described in section 3.1, there are 35 production sectors, but not all of them are active. The outputs of inactive sectors are zero, and this is formalized in equation (1) where $q_t(PC, S)$ is the output of each species in each production category at time t.

$$q_t(PC, S) = 0 \text{ if } \nu(PC, S) = 0 \quad (1)$$

We use a five-element set, $CI = [Labour, Feed, Seed, Energy, Other]$, to refer to the inputs and a triple, $X_t(PC, S, CI)$, to denote the quantity of every input used in every sector at time t. These quantities are zero if the inputs are not used, or if the sector is not active. The input demands of active sector are presented in equation (2) where $A_t^x(PC, S, CI)$ is the input required to produce one unit of output, which varies across the fish groups and production sectors. From here when a full description of a set has been defined, the shortcut (.) is used for compactness, unless when purposely avoiding possible confusions.

$$X_t(.) = q_t(PC, S) \times A_t^x(.) \quad (2)$$

Following the World Bank's IMPACT model (Robinson, 2015:16), the fish supply in each active sector is determined in equation (3), which specifies that the supply will respond to the rate of return in fishing.

$$q_t(PC, S) = A^q(PC, S) \times \left(\frac{\Pi_t(PC,S)}{\Pi_{base}(PC,S)}\right)^{\epsilon^q(PC,S)} \quad (3)$$

where $\Pi_t(.) = \frac{p_t^f(PC,S) q_t(PC,S)}{\sum_{CI} w_t(CI) X_t(PC,S,CI)}$ is the rate of return (BCR) at time t; $p_t^f(.)$ is the farm-gate price of fish which could vary across different types of production, $w_t(.)$ is the price of inputs; $\epsilon^q(.)$ is the response elasticity of supply to the rate of return, and $A^q(PC, S)$ is a shifting parameter.

2.2.2 Fish consumption demand

To model the demand for fish in each region, we use a double-layer structure for a representative consumer in this study. Here consumers decide the quantity of each good to maximize the utility with a certain budget, e.g., how much to spend on each fish group and then within each group how much to spend on domestic and imported products, if any (Dey et al., 2005). Both layers can be modeled using the Armington preference (Armington, 1969) which allows for a certain level of substitutability, e.g., when a product becomes more expensive, the consumer might substitute it with similar products. Compared to the iso-elasticity specified by the World Bank's IMPACT model, this approach is less mathematically tractable, but it is consistent with consumer theory such as the Engle and Cournot aggregation properties.

For each of the regional consumer, the double-layer optimization for the consumer decision is presented in equations (4) and (5). Here, $e_t^{c,r}(.)$ is a seven-element vector of the spending on each fish group (both domestic and imported if any) at time t of region r; $y_t^r = y_{base}^r \Pi_{t=base+1}^{base+T}\left(1+g_t^{I,r} \times \epsilon^r\right)$ is the per-capita spending on fish at time t of region r with $g_t^{I,r}$ being the annual rate growth rate of income and ϵ^r is the elasticity of per-capita spending on fish with respect to income ; $\sigma^{c,r}$ is a regional scalar constant-elasticity-of-substitution coefficient (CES); $Q_t^{d,r}(.)$ and $Q_t^{i,r}(.)$ are the consumption quantities of domestic and imported fish by a representative consumer of region r respectively; $p_t^{d,r}(.)$ and $p_t^{i,r}(.)$ are the prices paid by region r for domestic and imported fish; $\sigma^r(S)$ is a regional vector of seven CES coefficients, one for each species group; $A^{d,r}(S)$, $A^{i,r}(S)$, and $A^{c,r}$ are regional vectors of coefficients which can, without the loss of generality, be normalized such that $A^{d,r}(S) + A^{i,r}(S) = 1$ and $\sum_S A^{c,r}(.) = 1$.

$$\max_{e_t^{c,r}(S)} \left[\sum_S A^{c,r}(.)e_t^{c,r}(.)^{1-\frac{1}{\sigma^{c,r}}}\right]^{\frac{\sigma^{c,r}}{1-\sigma^{c,r}}} \text{subject to } \sum_S e_t^{c,r} = y_t^r \tag{4}$$

$$\max_{Q_t^{d,r}(S)Q_t^{i,r}(S)} \left[A^{d,r}(S)Q_t^{d,r}(S)^{1-\frac{1}{\sigma^r(S)}} + A^{i,r}(S)Q_t^{i,r}(s)^{1-\frac{1}{\sigma^r(s)}}\right]^{\frac{\sigma^r(S)}{1-\sigma^r(S)}}$$

$$\text{subject to } p_t^{d,r}(.)Q_t^{d,r}(.) + p_t^{i,r}(.)Q_t^{i,r}(.) = e_t^c(.) \tag{5}$$

Solving the optimization in equations (4) and (5) is a straightforward calculus exercise though a little lengthy. The quantity demanded for domestically produced and imported fish by a representative consumer can be derived as in equation (6).

$$Q_t^{\mu,r}(.) = e_t^{c,r} \frac{\left(\frac{A^{\mu,r}(.)}{p_t^{\mu,r}(.)}\right)^{\sigma^r(.)}}{\sum_{\theta\in[d,i]} p_t^{\theta,r}(.)\left(\frac{A^{\theta,r}(.)}{p_t^{\theta,r}(.)}\right)^{\sigma^r(.)}} \quad \text{for} \quad \mu = [d,i] \tag{6}$$

where $e_t^{c,r}(.) = y_t^r \frac{p_t^{c,r}(S)\left(\frac{A^{c,r}(S)}{p_t^{c,r}(S)}\right)^{\sigma^r(S)}}{\sum_S p_t^{c,r}(S)\left(\frac{A^{c,r}(S)}{p_t^{c,r}(S)}\right)^{\sigma^r(S)}}$ with $p_t^{c,r}(S) = \left[\sum_{\theta\in[d,i]} p_t^{\theta,r}(.)\left(\frac{A^{\theta,r}(.)}{p_t^{\theta,r}(.)}\right)^{\sigma^r(.)}\right]^{\frac{1}{1-\sigma^r(.)}}$

The market demand for domestic and imported fish, $q_t^{d,r}(S)$ and $q_t^{d,r}(S)$, can be formalized as in equation (7).

$$q_t^{\mu,r}(.) = N_t^r Q_t^{\mu,r}(.) \text{ for } \mu = [d,i] \tag{7}$$

where $N_t^r = N_{base}^r \Pi_{t=base+1}^{base+T}(1+g_t^{n,r})$ is the population of regional r at time t which grows at an annual rate of $g_t^{n,r}$.

2.2.3 Fish export

The demand for fish export is specified with a constant elasticity function in equation (8):

$$q_t^{ex}(S) = Z_t^{ex}(S) \times \left(\frac{p_t^{ex}(S)}{p_t^{w}(S)}\right)^{\epsilon^{ex}(s)} \tag{8}$$

where $q_t^{ex}(.)$ is the export quantity of the species (if any) at time t; $\epsilon^{ex}(S) \leq 0$ is the elasticity coefficients for export demand showing how the export quantity responds to the ratio between domestic and the world price; and $Z_t^{ex}(S)$ is price-shift coefficients.

2.2.4 Fish price formation and market clearing condition

We denote $T_t^{d}(.)$ and $M_t^{d,r}(.)$ as sales-tax rates and domestic margin, which might vary across species and regions. Using this notation, the consumer price of domestic fish can be calculated by incorporating the domestic margin and the sale-tax rate into the average farm-gate price as in equation (9).

$$p_t^{d,r}(S) = \frac{\sum_{PC} p_t^{f}(PC,S) q_t(PC,S)}{\sum_{PC} q_t(PC,S)} \left(1 + M_t^{d,r}(S)\right) \left(1 + T_t^{d}(S)\right) \tag{9}$$

The consumer price of imported fish equals the world (CIF) price plus import tax (if any) as presented in equation (10) where $p_t^{w}(S)$ is the world price, $T_t^{i}(S)$ is the import tax rate, and $M_t^{i,r}(.)$ is the import margin.

$$p_t^{i,r}(S) = p_t^{w}(S) \left(1 + M_t^{i,r}(S)\right) \left(1 + T_t^{i}(S)\right) \tag{10}$$

The export price of fish equals the farm gate price plus export margin and export tax (if any) as presented in equation (11) where $M_t^{ex}(S)$ and $T_t^{ex}(S)$ are the export margin and export-tax rates.

$$p_t^{ex}(S) = p_t^{f}(S)\left(1 + M_t^{ex}(S)\right)\left(1 + T_t^{ex}(S)\right) \tag{11}$$

The market-clearing condition requires the total (domestic) supply from all production sectors be equal to the consumer demand for domestic fish plus export as in equation (12).

$$\sum_{PC} q_t(PC,S) = \sum_{r \in R} q_t^{d,r}(S) + q_t^{ex}(S) \tag{12}$$

2.2.5 Nutrient intake

The model can be used to project the nutrition intake via fish consumption. We denote $V_t^{PC}(S)$ as the nutrition content per unit of quantity of species S which may vary across production categories and so $V_t^{i}(S)$ is the nutrition content per unit of quantity of imported fish. The nutrition intake per person can be estimated using equation (13), which specifies that the nutrition intake from fish consumption is the sum of the nutrition intake from domestic and imported fish.

$$V_t^{r} = \frac{q_t^{d,r}(S) \times \sum_{PC}\left[V_t^{PC}(S) \times \frac{q_t(PC,S)}{\sum_{PC} q_t(PC,S)}\right] + q_t^{i,r}(S) \times V_t^{i}(S)}{N_t^{r}} \tag{13}$$

2.3 Model calibration

We calibrate the multi-species-multi-sector equilibrium model in specified section 3.2 following the process described by Dawkins et al. (2001). In the production side, the coefficients $A_t^x(PC, S, CI)$ and $A^q(PC, S)$ in equations (2) and (3) are calibrated by combining the data in Appendix 4 and the elasticity of supply with respect to the rate of return $\epsilon^q(PC, S)$ which is referred from the database of the fish IMPACT model.

We also calibrate the demand side of the model in a similar way. The parameters in the double-layer preference structure in equations (4) and (5) and also the export price-shift parameters in equation (8) are calculated by combining the data with the CES coefficients σ^C, $\sigma(S)$ and $\epsilon^{ex}(S)$. These coefficients are fine-tuned to best fit with the average of the two empirical estimates of the price elasticity for fish in Nigeria, i.e., -1.2593 estimated by Lufumpa et al. (2016:t12) and -0.489 estimated by Muhammad et al. (2011:42). The values for domestic and export margins in equations (9) and (11) are calculated directly from the data. Export price-shift parameters are calculated from the data, and the nutrition content coefficients in equation (13) are provided in Table 2.

3. Scenarios

Alternative scenarios were developed during two stakeholder consultation workshops conducted in Abuja (Jan 2019) and Ibadan (June 2019). The third stakeholder consultation workshop was conducted in Ibadan in December 2019 to validate the preliminary projection results. In this meeting, the business-as-usual (BAU) projection results were revised and updated taking into account the inputs and comments from the stakeholder consultation. Invited participants (government, academia, private sector and NGO) are from different field of expertise, covering aquaculture, fisheries, trade and economics to provide data or information and expert opinion for alternative scenarios exploration.

The analysis generated future fish supply and demand based on five scenarios, including business-as-usual (BAU) and four alternative scenarios. The BAU scenario is characterized by a set of model parameters to reflect a continuation of past trends into the future with adjustment to align projections with country capacities and endowments. These trends take into account knowledge from published sources, feedback from country stakeholder consultation. Alternative scenarios were developed during a stakeholder consultation workshop to investigate the key prospects and challenges of the fish sector in Nigeria. The first scenario--Hick-neutral technological progress, focuses on the overall improvement in aquaculture production technology that productivity would increase by 25% during 2020-2050 period. The second scenario--increase tax on imported fish, investigates the impact of increase imported fish price of 10% due to import tariff. The third scenario--climate change, assumes a 20% reduction of capture fisheries output by 2050 compare to 2015. The final scenario--increase fishery management, analyse an increase of 1.5% per year from 2015 to 2050 as a result of stock enhancement and effective fisheries management.

4. Results

4.1 Business-as-usual (BAU)

We calibrate the model under the BAU scenario from 2020 to 2050. In this scenario, we assume different dynamics for capture fisheries and aquaculture production to reflect the historical data and projected trends. In the 2010-2015 period, capture fisheries production in Nigeria was growing at an average rate of 2.5% while the number for the world was around zero (FAO, 2018:f1). For this reason, we assume that the growth of capture fisheries production would slow down from 2.5% year to 1.5% from 2020 to 2025, then the growth rate would further reduce from 1.5% to zero in the following ten years and remain stable after 2035.

Aquaculture production has been growing relatively fast in Nigeria. The growth rate was, on average, 11% per year during the period 2010-2015, though interannually varied. In the BAU scenario, we assume that aquaculture production in Nigeria would double between 2015 and 2025, i.e., an average growth rate of 7% per year. From 2025 to 2035, aquaculture growth would slow down to 5%, and the growth rate would further reduce to 2% by 2050.

Table 1 shows that Nigeria produced nearly 1.1 million tons of fish at the farm-gate value of 2.5 billion USD in total in 2015. Aquaculture accounts for 30% of the output and 37% of the value. The total fish production is expected to increase from 1.3 to 2.8 million tonnes during the 2020-2050 period with most of this increase driven by aquaculture. The aquaculture output would increase by 4.5 times between 2020 and 2050, from 0.33 to 1.8 million tonnes. Since aquaculture is growing much faster than capture fisheries (6.3% vs 1.1% from 2020-2035) aquaculture production will exceed the capture fisheries production by mid 2030 (Figure 1).

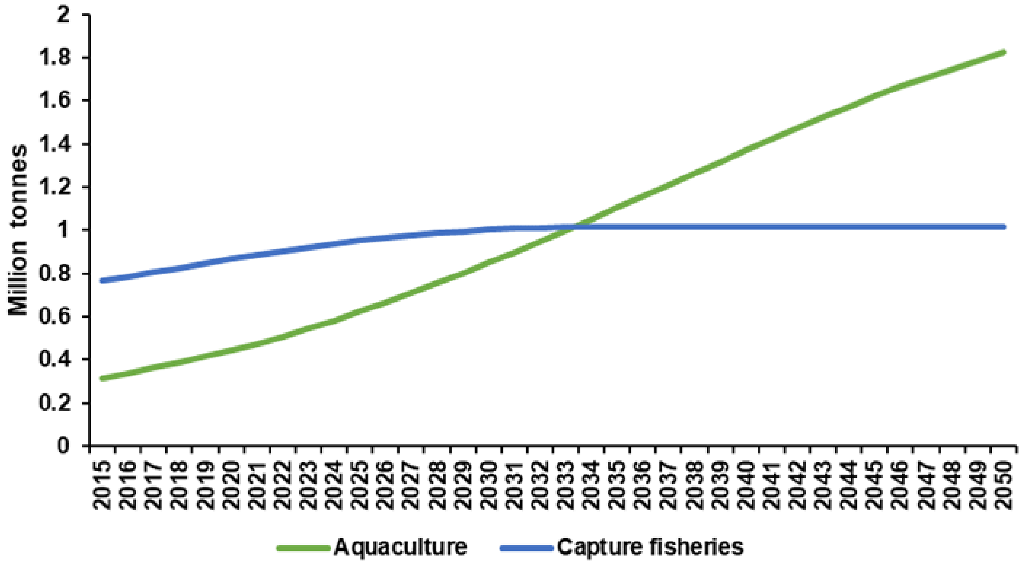

Figure 1. Future capture fisheries and aquaculture production in Nigeria, 2015-2050

We assume that the population growth varies across regions due to urbanization. The population would grow faster in urban than in rural areas. This trend reflects historical statistics where the population of the urban north grew at an average rate of 3.6% per year while the population of the rural north grew at only 1.7% per year over the 2005-2014 period. The urbanization trend was even stronger in the South, where the urban south population grew at a rate of 3.9%, and the rural south population declined by 1.2% (Table 4). In the BAU scenario, we assume that the population dynamics in the regions would be proportional to the historical urbanization trend and fit with the overall population growth rate as projected by the United Nations.

Table 4. Nigerian regional population growth

Region	2015 population (million people)	Shares in total population (%)	2005-2014 average growth rate (%)
North rural region	70.4	38.9	1.7
North urban region	27.3	15.1	3.6
South rural region	24.0	13.3	-1.2
South urban region	59.4	32.8	3.9

We solve the model with the BAU assumption and summarize the projection of fish production. The total fish production would increase over time from 1.4 to 2.8 million tonnes during the 2020-2050 period. Most of this increase would be driven by the aquaculture sector. The aquaculture output would increase by 4.5 times between 2020 and 2050, from 0.48 to 1.8 million tonnes. The aquaculture sector would have an increasing share in the total output, because of its faster growth, and exceed the capture fisheries sector around the middle of the 2030 decade.

The output of all fish groups would increase over time, though at different growth rates (Figure 2). Specifically, catfish and tilapia would grow fastest because they are the key groups in aquaculture and not constrained by the limited capacity of the capture fisheries. The next groups are carps, Nile perch, and snakehead. Species that are mainly capture fisheries, such as clupeid and shrimps, are subject to the limited capacity of the capture fisheries, and their production growth would be more sluggish.

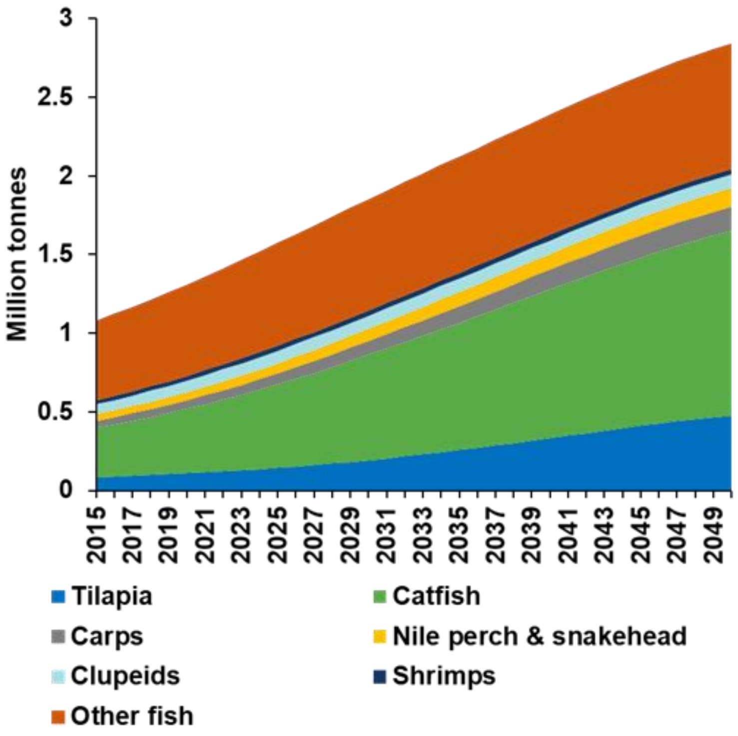

Figure 2. Future fish production by fish group

Table 3 illustrates that per-capita fish consumption in the North was low, 5.4 and 7.1 kg/person/year in the rural and urban regions, respectively. People living in the South consumed more fish, with the per-capita consumption of around 17.1 and 16.1 kg/person/year in the rural and urban regions – relatively close to the world average fish consumption. Average fish prices also show a significant North-South difference where the price in the South is around 50% higher than in the North. However, the difference in prices does not necessarily imply the level of fish availability because the price may also reflect the quality of fish consumed across regions.

The dynamics of total fish consumption and its composition in terms of domestic and imported fish. The fish consumption would increase over time as fuelled by economic and population growth. This increase would be matched by domestic production and increases in imports. As the growth of the aquaculture sector would slow down while the capture fisheries remaining stable, imports would play a more important role in meeting the increasing demand for fish. The country-average per-capita fish consumption would increase from 11.2kg/person/year in 2020 to 14.8kg/person/year in 2050 (Figure 3).

Figure 4 shows the nutrition content of fish consumption in terms of protein and vitamin A intake. The dynamic of nutrition intake is similar to fish consumption. All four regions show an increasing trend, but the regional variation would be wide for both protein and Vitamin A intake.

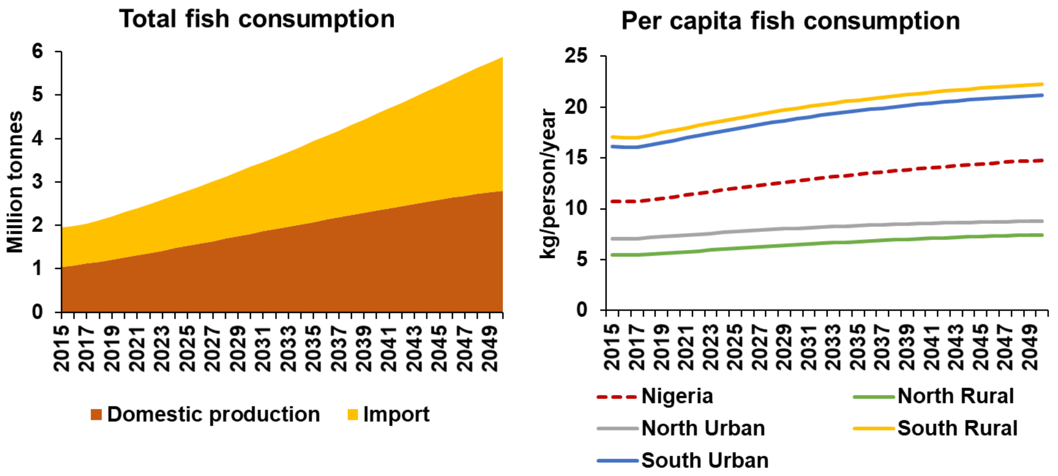

Figure 3. Future fish consumption in Nigeria

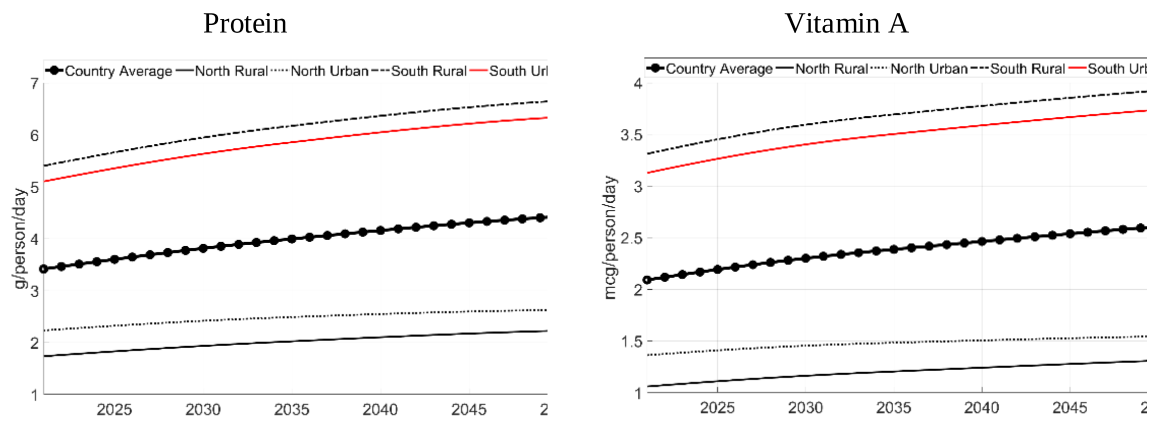

Figure 4. Future key nutrient intake and regional distribution

4.2 Alternative Scenarios

4.2.1 Hick-neutral technological improvements

Table 5 summarises the result of this scenario and compare it with the BAU. As a result of the Hick-neutral technological progress, the growth of aquaculture would be significantly faster than in the BAU, contributing to higher production output and fish consumption in all regions. The faster growth rate of aquaculture would also increase the demand for inputs.

Table 5. Hick-neutral technological improvements

Group	Indicators	BAU			With hick-neutral technology progress		
		2030	2040	2050	2030	2040	2050
Macro indicators (million tonnes)	Total production:	1.9	2.4	2.8	1.9	2.6	3.2
	- Aquaculture	0.8	1.4	1.8	0.9	1.6	2.2
	- Catch	1.0	1.0	1.0	1.0	1.0	1.0
	Total consumption	3.3	4.6	5.9	3.4	4.8	6.2
	- Import	1.5	2.2	3.1	1.5	2.2	3.1
Per-capita fish consumption (kg/person/year)	Country average	12.8	13.9	14.8	13.0	14.5	15.7
	- North rural	6.5	7.0	7.4	6.6	7.3	7.9
	- North urban	8.1	8.5	8.8	8.3	8.9	9.3
	- South rural	19.9	21.3	22.2	20.5	22.2	23.5
	- South urban	18.9	20.3	21.2	19.3	21.1	22.4
Input quantity index (year 2015≡100)	Labor*	174	223	258	173	219	250
	Seed*	261	412	538	257	398	510
	Feed*	279	466	635	275	450	601

Note: Starred indicators rounded to integers, others rounded to the nearest tenth.

4.2.2 Increase tax on imported fish

The next scenario focuses on the impact of taxing imported fish. Nigeria has a significant fish deficit, i.e., domestic production could not meet the demand for fish. As a result, the country must import more than 0.9 million tonnes of fish in the base year 2015, around 46% of the fish consumption. The fish deficit means a certain amount of foreign exchange reserves must be used on fish imports, and a common instrument to control the outflow of the foreign exchange is import tariff. In this scenario, we calculate the projection outcome assuming that the price of imported fish would increase by 10% as a result of import tariff. The result is presented in Table 6. It shows that import tariffs could not eliminate the fish deficit, and Nigeria would still be a fish importer. The tariff, however, could help reduce fish import by around 7-9% between 2040 and 2050. Another impact of the tariff is the reduction in fish consumption. The impacts on other indicators are not significant.

Table 6. Increasing tax on imported fish

Group	Indicators	BAU			10% tax on imported fish		
		2030	2040	2050	2030	2040	2050
Macro indicators (million tonnes)	Total production:	1.9	2.4	2.8	1.9	2.4	2.8
	- Aquaculture	0.8	1.4	1.8	0.8	1.4	1.8

	- Catch	1.0	1.0	1.0	1.0	1.0	1.0
	Total consumption	3.3	4.6	5.9	3.2	4.4	5.6
	- Import	1.5	2.2	3.1	1.4	2.0	2.8
Input quantity index (year 2015≡100)	Labor*	174	223	258	174	223	258
	Seed*	261	412	538	261	412	538
	Feed*	279	466	635	279	466	635
Production Profitability	BCR Aquaculture	1.2	1.2	1.3	1.2	1.2	1.3
	BCR Catch	1.8	2.3	3.0	1.8	2.3	3.0
Per-capita fish consumption (kg/person/year)	Country average	12.8	13.9	14.8	12.2	13.3	14.1
	- North rural	6.5	7.0	7.4	6.2	6.7	7.1
	- North urban	8.1	8.5	8.8	7.8	8.2	8.4
	- South rural	19.9	21.3	22.2	19.1	20.4	21.2
	- South urban	18.9	20.3	21.2	18.1	19.4	20.2

4.2.3 Climate change

Climate change could have negative impacts on the capture fisheries sector of Nigeria (Ipinjolu et al., 2014) and potentially reduce the catch output. The size of the output reduction varies across assumptions about possible climate realizations, mitigation strategies, and estimation approaches, ranging from 10% to 34% by 2050 (Frost et al., 2012).

Given these estimates, we calculate a projection outcome assuming that climate change would cause a 20% reduction in the catch output, i.e., namely the catch output in 2050 was 20% lower than in the base year 2015. Table 7 presents the result of this scenario. The reduction in the catch output would reduce fish supply causing an overall increase in fish price which increases the profitability of fish farmers. As a result, aquaculture would grow faster than in the BAU scenario, partially offset the reduction in the capture fisheries. Feed and seed quantities used in aquaculture would increase faster while the labor input would reduce because of the contraction of the labor-intensive catch sector. Fish consumption would be lower than in the BAU scenario, and the impact on fish imports is not significant.

Table 71. The likely negative impacts of climate change on the capture fisheries

Group	Indicators	BAU			With climate change impacts		
		2030	2040	2050	2030	2040	2050
Macro indicators (million tonnes)	Total production:	1.9	2.4	2.8	1.6	2.1	2.6
	- Aquaculture	0.8	1.4	1.8	0.9	1.5	2.0
	- Catch	1.0	1.0	1.0	0.7	0.7	0.6
	Total consumption	3.3	4.6	5.9	3.1	4.3	5.6
	- Import	1.5	2.2	3.1	1.5	2.2	3.1
Per-capita fish consumption (kg/person/year)	Country average	12.8	13.9	14.8	12.0	13.2	14.1
	- North rural	6.5	7.0	7.4	6.1	6.7	7.1
	- North urban	8.1	8.5	8.8	7.6	8.1	8.4
	- South rural	19.9	21.3	22.2	18.6	20.2	21.2
	- South urban	18.9	20.3	21.2	17.6	19.2	20.2
Input quantity index (year 2015≡100)	Labor*	174	223	258	158	205	240
	Seed*	261	412	538	286	445	576
	Feed*	279	466	635	305	501	676

4.2.4 Fishery management and stock enhancement

Finally, we analyze the fishery management and stock enhancement scenario where the capture fisheries output would increase over time until 2050. In particular, we calculate the projection result assuming the capture fisheries output would increase at 1.5% a year until 2050 instead of the BAU scenario where the capture fisheries output would grow only until 2025, then slow down and level off.

Table 8 summarises the projection outcome of this optimistic scenario. The expansion of the fisheries sector would increase fish production and consumption. The increase in fish supply would reduce the profitability of fish farmers, as compared to the BAU scenario. As a result, the aquaculture sector output would be lower with less feed and seed. The labour quantity would be higher than in the BAU scenario due to the expansion of the capture fisheries which is labour-intensive.

Table 8. Fishery management and stock enhancement

Group	Indicators	BAU			With the optimistic expansion of capture fisheries		
		2030	2040	2050	2030	2040	2050
Macro indicators (million tonnes)	Total production:	1.9	2.4	2.8	1.9	2.5	3.1
	- Aquaculture	0.8	1.4	1.8	0.8	1.3	1.7
	- Catch	1.0	1.0	1.0	1.0	1.2	1.4
	Total consumption	3.3	4.6	5.9	3.4	4.7	6.1
	- Import	1.5	2.2	3.1	1.5	2.2	3.1
Per-capita fish consumption (kg/person/year)	Country average	12.8	13.9	14.8	12.8	14.3	15.4
	- North rural	6.5	7.0	7.4	6.5	7.2	7.8
	- North urban	8.1	8.5	8.8	8.1	8.8	9.1
	- South rural	19.9	21.3	22.2	20.0	21.9	23.2
	- South urban	18.9	20.3	21.2	19.0	20.8	22.2
Input quantity index (year 2015≡100)	Labor*	174	223	258	175	232	278
	Seed*	261	412	538	260	399	510
	Feed*	279	466	635	277	452	605

Table 9 summarized the comparison of fish supply and demand in different scenarios in 2030 vs 2015.

Table 9. Comparison of Nigerian BAU and in different alternative scenarios in 2030

Item	2015	2030				
		BAU	Hick Neutral	Increased Import Tax	Climate Change	Increase Fishery Management
Total fish (thousand tonne)	1,083	1,853	1,924	1,851	1,630	1,870
Capture fisheries (thousand tonne)	766	1,003	1,003	1,003	696	1,026
Aquaculture (thousand tonne)	317	850	921	848	934	844
Fish consumption (kg/person/year)	10.7	12.8	13.0	12.2	12.0	12.8

Fish import (thousand tonne)	906	1,541	1,542	1,405	1,534	1,541
Fish export (thousand tonne)	12	5	5	7	0.8	5
Total population (million)	181	262				

5. Policy implications

First, the demand for fish in Nigeria would increase relatively fast as fuelled by economic and demographic growth. Domestic fish production would not be adequate to meet the growing demand, and Nigeria would remain a fish importer. The import quantity would increase during the period from 2020 to 2050 in all considered scenarios.

Second, aquaculture plays an increasingly important role in the fish sector of Nigeria. Aquaculture is currently less than 50% of the capture fisheries in terms of production output, but it would likely exceed the capture fisheries sector before 2050 to become the largest source of fish supply. The growth of aquaculture would potentially help reduce over-exploitation incentives driven by the increasing fish demand and improve the sustainability of marine resources.

Third, the expansion of the aquaculture sector would not be possible without substantial increases in the quantities of feed and seed, and so a reliable supply of these inputs is vital for the development of aquaculture. Currently, aquaculture farmers must rely on imported inputs, which might be subject to uncertainties. Promoting industries for aquaculture inputs within the country could potentially increase the reliability of the input supply and contribute to the development of the aquaculture sector.

Fourth, our scenario analysis highlights the importance of promoting technological progress in aquaculture. Technological progress, either in the supply of inputs or the production of fish, would help farmers produce fish with less cost and improve their rate of return. This is particularly important when fish farming in Nigeria is currently behind in new species (e.g., tilapia) as compared to best-performing countries. Our analysis shows that promoting technological progress would viably accelerate the expansion of aquaculture and improve the welfare of fish consumers in Nigeria.

Fifth, financial and monetary policies provide some instruments with both positive and negative impacts on the fish industry. For instance, reducing tax on imported feed could reduce the production cost for farmers, but it could also increase the competition faced by domestic feed suppliers, most of them are likely new and have less experience in the industry compared to foreign suppliers. Increasing the import tariff on fish could reduce fish import and, to some extent, protect domestic fish suppliers on the one hand. On the other, the tariff could make the imported fish relatively more expensive and reduce consumer welfare. Currency revaluation and devaluation might also change the relative prices between domestic and imported products, and they usually improve the benefit of fish suppliers at the cost of worsening the welfare of fish consumers or vice versa. Thus, we recommend that the application of the tax and currency instruments should be thoroughly considered, particularly when their impacts could be far beyond the fish sector. In most situations, they should be used to achieve short-term objectives rather than as long-term development tools.

Sixth, the capture fisheries sector is subject to climate change uncertainties, more likely with negative impacts. As capture fisheries is the largest source of fish supply in Nigeria, at least in the short term, any impacts of climate change on capture fisheries would also spread to other stakeholders in the fish industry, including aquaculture farmers, input suppliers, and fish consumers. For this reason, climate uncertainties should be taken into account in the development plan of the fish industry in Nigeria.

Finally, the regional difference in Nigeria is wide. People in the South consume significantly more fish than people in the North, though fish consumption would increase in both regions. While the per-capita fish consumption in the South approaches the world average, the consumption in the North would always be only a fraction, both in rural and urban areas. The wide regional difference implies that while country-average fish consumption might not be too low, nutrition concerns may arise in some regions, likely in the northern part of the country.

6. Conclusion

We develop a multi-species-multi-sector-multi-region equilibrium model to provide projections for Nigeria's fish industry until 2050. The model is calibrated using real-life data in 2015 as a baseline together with some econometrical estimates and forecasts on the dynamics of driving factors. Using the model, we consider a range of plausible scenarios to provide insights and policy implications for the fish industry in Nigeria. Though specific results vary across scenarios, one of the key findings of the analysis is the expansion of aquaculture in Nigeria. Aquaculture plays an increasing role in fish supply to meet the fast-growing demand for fish in the country. Aquaculture would likely exceed the capture fisheries to become the largest source of fish supply by mid 2030.The model we develop can be applied to other countries as it could be calibrated with indispensable data. If more detailed data become available, future research may extend our framework by formalizing the behaviour of other stakeholders in the fish supply chain such as feed producers who supply inputs to fish producers or fish retailers who connect fish producers and consumers.

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Appendix 1: Fish group classification

Fish group	Scientific name	Common name
Tilapia	*Oreochromis*	Tilapia
	-	Epiya
Catfish	*Chrysichthys nigrodigitatus*	Bagrid catfishes
	Parailia pellucida	Glass catfishes
	Ilisha africana	Naked catfishes
	Clarias;	Torpedo-shaped catfishes;
	Heterobranchus	North African catfish
	Synodontis spp	Upsidedown catfishes
	Clarias anguillaris	Mudfish
	Ariidae	Sea catfish
Carps	Cyprinidae *Cyprinus* *Labeo*	African carps; Common carps
Nile Perch & snakeheads	*Lates niloticus*	Nile/Niger perch
	Channa	Snakeheads
	Parachanna	Parachanna snakeheads
Clupeids	*Ethmalosa fimbriata*	Bonga shad
	Sardinella maderensis	Madeiran sardinella
	Sardinella *Clupea harengus*	Shawa; herrings
	Engraulis encrasicolus	Anchovies
	Sierrathrissa leonensis	Herrings
	Sardina pilchardus	Pilchards
	Ilisha africana	West African Ilisha
	-	Freshwater sardines (if any)
Shrimps and prawns	*Natantia* *Peneaus*	Ede (Crayfish); Natantian decapods
	Penaeus notialis	Southern pink shrimp
	Penaeus	Prawn; Penaeus shrimp; White shrimp
Others	-	All other fishery products exclude aquatic plants
	Hydrocynus vittatus	African Tigerfish
	Hepsetus odoe	Kafue Pike
	Heterotis niloticus	Bony Tongue Fish/African Arowana
	Xenomystus nigri/Gymnarchus niloticus	African Knife fish/Aba
	Papyrocranus afer	Reticulate knifefish
	Sciaenidae	Croakers
	Lutjanidae	Snapper
	Polynemidae	Threadfin
	Serranidae	Grouper
	Merluccius	Hake

	Gadus	Cod
	Chloroscombrus chrysurus	Atlantic Bumpers
	Scombridae	Mackerel
	Mormyrus lacerda	Mormyrids -Elephant Snout Fish
	Gobiiformes	Mudskipper
	Citharinus citharus	Moonfish
	Caranx fischeri	Longfin Crevalle Jack
	Soleidae	Common Sole
	Sphyraena	Barracuda
	Katsuwonus pelamis	Skipjack Tuna
	Crassostrea tulipa	Mangrove oyster
	Littorina littorea	Periwinkles
	-	Bivalves
	-	Crayfish
	-	Crabs
	Distichodus spp	Grass-eaters nei

Note: The grouping of Nile perch & Snakeheads is based on the classification in the UNTradeCom Database (United Nations, 2019) and FAO Global Fishery and Aquaculture Commodities Statistics (FAO Statistics). Other groupings are based on ASFIS species grouping (a different way to classify the fish).