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Fish to 2050 in the ASEAN Region



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Fish to 2050 in the ASEAN Region

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List of abbreviations

AIT	Asian Institute of Technology
APFIC	Asia-Pacific Fishery Commission
ASEAN	Association of Southeast Asian Nations
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CGIAR	Consultative Group on International Agricultural Research
CTI-CFF	Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security
FAO	Food and Agriculture Organization
FIPS	Fisheries and Aquaculture Statistics and Information Branch
GDP	gross domestic product
GFSF	Global Futures and Strategic Foresight
IFPRI	International Food Policy Research Institute
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
ISSCAAP	International Standard Statistical Classification of Aquatic Animals and Plants
IUU	illegal, unreported and unregulated (fishing)
L&F	CGIAR Research Program on Livestock and Fish
MSY	maximum sustainable yield
NACA	Network of Aquaculture Centers in the Asia-Pacific
NGO	nongovernmental organization
OECD	Organisation for Economic Co-operation and Development
PEMSEA	Partnerships in the Environmental Management for the Seas of East Asia
PIM	CGIAR Research Program on Policies, Institutions and Markets
RPOA-IUU	Illegal, Unregulated, and Unreported Regional Plan of Action
SEAFDEC	Southeast Asian Fisheries Development Center
USDA	United States Department of Agriculture

Abstract

The Association of Southeast Asian Nations (ASEAN) has emerged as a global fish producer, owing to the rapid growth of aquaculture in Southeast Asia and its large offshore fishing fleet. Fish is a regional commodity that is traded globally, and this region is at the frontline of the global trend toward meeting seafood demand by 2050. Fisheries and aquaculture are increasingly becoming a primary source of protein and micronutrients, foreign exchange, livelihoods and well-being for the population in the region. Therefore, it is imperative for ASEAN decision-makers to enhance policies nationally and regionally to maximize the synergies between socioeconomic development and protecting natural resources and the environment in the region.

Using the International Model for Policy Analysis of Agriculture Commodities and Trade (IMPACT) of the International Food Policy Research Institute (IFPRI), with an updated fish model developed in collaboration with WorldFish, the Fisheries and Aquaculture Department of the Food and Agriculture Organization (FAO), and the University of Arkansas at Pine Bluff, the business-as-usual projection of *Fish to 2050* in the ASEAN region was created taking into account industry-specific biophysical and socioeconomic factors, such as environmental management and ecosystem carrying capacity plus socioeconomic targets defined by national governments during a stakeholder consultation workshop at WorldFish in June 2016.

In the ASEAN region, fish production will continue to grow and likely to reach nearly a quarter share of global fish output in 2030 and then sustain this share to 2050. Aquaculture is expected to supply more than half of the fish consumed in the ASEAN region in the coming decade. *Pangasius* and other catfish, carp and tilapia will continue to be the major species produced from aquaculture. Continued dominance of capture fisheries as a source of fish supply is projected in the region through to 2050. Higher per capita fish and fish oil consumption will increase the nutrient intake from fish in the ASEAN region. Regional fish and fishery products will continue to be broadly traded given the balance of regional supply and demand in the near future. Aquaculture and capture fisheries have important, complementary roles to play in ensuring that fish remains available and affordable in the region. Policies to promote sustainable aquaculture expansion and law enforcement in fisheries management are critical to ensuring sustainable growth of both sectors. WorldFish has made significant updates to the current IMPACT fish model in producing these ASEAN projection results. Yet continued efforts are needed to address several limitations of the current model and enhance the robustness of future projections.

Introduction

The world's population is estimated to reach 9.7 billion by 2050 from its current level of 7.3 billion [1], with most of the increase occurring in developing countries. In a context of climate change, economic uncertainty and increasing competition for natural resources, feeding this population will be an important challenge. To meet this demand without significant price increases, it is estimated that food production will need to rise approximately 70–100% from the current production level by 2050 [2, 3]. Currently representing 20% of all animal protein supply [4, 5], fish will be a prominent future contributor to global food and nutrition security. Global demand for seafood continues to rise, driven by population growth, higher incomes, urbanization, growing international fish trade and increasing relative preference for seafood protein [6]. Preliminary estimates for 2015 showed that global annual per capita fish consumption reached a new record high of more than 20 kg [7].

However, fish production is not homogeneously distributed. In 2014, Asia accounted for 70.8% of global fish production (88.9% of aquaculture and 56.5% of capture production), excluding aquatic plants. China alone produced 37.5% and consumed 37.1% of the world's food fish [8]. South Asia accounted for 9.3% of global fish supply, with India and Bangladesh as the region's top producers, while Southeast Asia accounted for 18.3% [8]. Africa, Latin America, Europe and North America accounted for 6.2%, 8.1%, 10% and 4% respectively. Over the past two decades, most of the growth in global fish production has come from aquaculture [8] as world capture fisheries have leveled off since the 1990s at about 90 million tons annually (approximately 70 million tons for food) [7, 9]. The majority of fish production, especially for farmed fish, occurs in developing countries in the south where competition for natural resources for food production, such as land, water and ecosystem services, is high.

The fish sector provides income, opens up employment opportunities, alleviates poverty and improves food and nutrition security in developing countries directly through production and indirectly across value chains. FAO [7] estimated that 56.6 million people globally (36% full time, 23% part time) were engaged in the primary sector of capture fisheries and aquaculture in 2014. Of this, 84% were based in Asia, followed by 10% in Africa. Although statistics are in many cases unreliable, particularly for small-scale fisheries, the number of people employed in capture fisheries appears to have remained steady since 2000, while the proportion of workers engaged in aquaculture has nearly doubled, from 17% in 1990 to 33% in 2014. Of the 18 million people engaged in fish farming, 94% were in Asia [7]. Also, three quarters of the countries where fish contributes more than one-third of animal protein in the diet are from low-income, food-deficit nations [10].

With this uneven distribution of global fish production, international fish trade becomes an important mechanism to satisfy the rising fish demand worldwide. Fish represents one of the most traded agricultural products, with an estimate of about 78% of seafood products traded internationally [11]. Global fish trade has increased rapidly in the past few decades with rising net trade flows from developing to developed countries. About 10% of agricultural exports are fish products from capture fisheries and aquaculture. The value of the global fish trade exceeds the value of international trade in all other combined animal source foods [12]. Low- and medium-income countries play a pivotal role as they supply half of all fish exports by value and two-thirds by quantity [12]. Fish trade represents an important source of foreign currency earnings for many developing countries in the south.

Given the dynamic contexts of regional fish production, consumption and trade in the global food system, multiple issues need to be addressed to sustain fish as a critical future contributor to food and nutrition security worldwide. This is especially true given the rapid expansion of aquaculture production and the challenges for managing associated socioeconomic and environmental impacts. There is a strong need for decision-makers to understand the future trends of fish supply and demand, taking into account complex interactions across fish commodities and fish producing and consuming countries. To date, several foresight modeling reports, including the Organisation for Economic Co-operation and Development (OECD) agriculture outlook [9] and *Fish to 2030* [13], have provided an overview of future fish supply and demand observed in fish commodities and countries globally and regionally.

Fish is a regional commodity that is shared globally. ASEAN—defined by a 10-member bloc of Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam—is at the frontline of the global trend of meeting expanding seafood demand out to 2050. The ASEAN region has a combined gross domestic product (GDP) of more than USD 2.6 trillion, growing 4.7% per annum, and a population of 632 million in 2015 (8.6% of the world's population) [14]. Its population is projected to reach 790 million by 2050 [1], which will require a significant increase in food supply to meet the rising demand. By volume, fish production is four times that of poultry and 20 times that of cattle in the ASEAN region [5]. Over the past 15 years, ASEAN fish output has more than doubled. Aquaculture production in the ASEAN region has increased four-fold from 2000 to 2014, showing stunning high growth compared to other regions in the world. The ASEAN region has transitioned from small-scale capture fisheries, sold domestically or regionally, toward a mix of smaller-scale and larger-scale export-oriented fisheries. This transition was driven by the enormous increase in aquaculture production over the past 20 years. In terms of the value of aquaculture production, the 10 ASEAN countries combined earned around USD 23.8 billion in 2014 [8]. The ASEAN capture fisheries sector has doubled in the past 25 years. For aquatic plants, overwhelmingly seaweeds, three of the 10 ASEAN members are among the world's top 10 producing countries, with Indonesia accounting for more than one-third of world seaweed output. Combined production of aquatic plants from the ASEAN countries has also increased more than seven-fold over the past decade [8]. The growth of the ASEAN region's fish supply for human consumption is more than twice the population growth, inducing a rise in average per capita fish consumption. Among other regions, ASEAN's annual per capita fish consumption in 2013 was the highest in the world at 35.2 kg [8].

The importance of the contribution by fisheries and aquaculture to national economies is well recognized among ASEAN countries, particularly as a source of foreign exchange earnings, an employment creator and income generator, as well as in food and nutrition security. The region's fisheries and aquaculture sectors have exhibited sustained growth in both production and consumption. Nonetheless, future fish supply and demand in the ASEAN region also face a number of challenges, especially climate change, which will cause disruptions in ocean and aquatic ecosystems [15-18]. Other global challenges such as increasing demand for fishmeal and fish oil and the associated price increases of fish will also become key drivers of change, shaping the future seafood industry in the region.

This paper presents a baseline (business-as-usual) projection of fish supply, net trade, consumption and nutrition in the ASEAN region to 2050. It extends the previous work (*Fish to 2030* [13] by the World Bank, IFPRI and FAO) with the effort of updating parameters of the IMPACT model to replicate observed trends of fish supply in ASEAN countries and other top 10 fish producers in the world. The modeling process was also informed by a stakeholder workshop organized at WorldFish in Penang, Malaysia, in June 2016. This helped improve the model calibration by taking into account sector-specific biophysical and socioeconomic factors, such as environmental and ecosystem carrying capacity and socioeconomic targets defined by national governments in the ASEAN region.

Historical trends of fish in the ASEAN region

Production

In 2014, the 10 ASEAN countries together accounted for 18.3% (30.6 million tons) of world fish production (167.3 million tons) (Figure 1) [8]. Indonesia, Vietnam and Myanmar are among the top 10 fish producing countries globally. Excluding aquatic plants, Indonesia alone accounted for 6.4% of world output and Vietnam 3.8% in 2014. Aquatic plant production is as important as fish output in Indonesia. In 2014, the ASEAN region supplied 11.9 million tons of aquatic plants (41.8% of world output), with Indonesia alone producing 10.1 million tons of seaweed, almost equal to its total fish supply of 10.7 million tons [8]. The Indonesian government aims to continue this high growth rate in its national policy.

Over the past 25 years, aquaculture has been the fastest-growing food production sector in the world, surpassing rates of increase in terrestrial livestock and dairy production by a wide margin [5, 6, 13]. The ASEAN region is an important aquaculture producer, with its members together producing around 14.7% (10.9 million tons) of the world total in 2014. Growth in aquaculture production in the region has been dramatic at an annual average of 14% from 2008 to 2013. During the same period, China showed a growth rate of 6% annually, South America 6.9% and

Africa 10.4%. Compared to other regions in the world, the ASEAN countries have shown an exceptional rate of aquaculture growth. At the national level, more than half of Vietnam's fish production came from aquaculture. Nevertheless, not all ASEAN region contribute to the high growth of the aquaculture sector. Brunei, Laos and Singapore have almost no commercial aquaculture development [8].

World capture fisheries production has remained stable at approximately 90–95 million tons per year over the past two decades, albeit with some fluctuations. Nevertheless, capture fisheries in the ASEAN region increased their output at 2.8% per annum between 2000 and 2014 (Figure 1). The region's contribution to global fishery production has gradually increased from 5% in 1950 to 21.1% in 2014 [8]. Indonesia was the second-largest fisheries producer (6.9% of world capture fisheries tonnage) after China in 2014. Indonesia, Myanmar and Vietnam each increased its catch by more than 100 thousand tons in 2014 compared to 2013 [8]. Despite notable increases from capture fisheries, the ASEAN region's share of aquaculture in total fish production has grown from 17% in 2000 to 35.5% in 2014, which implies that more than one-third of the current total production of food fish came from aquaculture (Figure 2) [8].

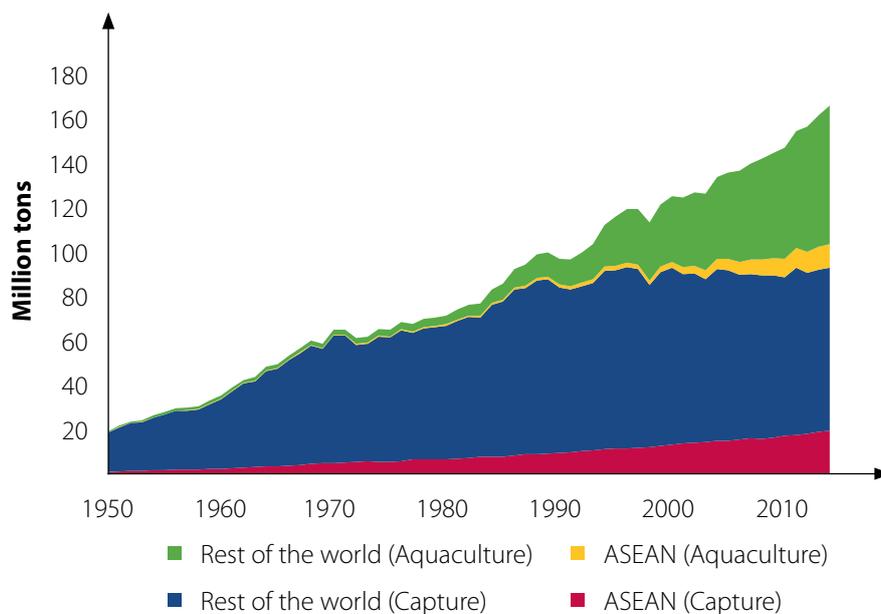


Figure 1. Global and ASEAN capture fisheries and aquaculture (excluding aquatic plants) production share, 1950–2014.

Figure 3A illustrates the share of five main fish species cultured in the ASEAN region by weight: catfish (22%), tilapia (17%), shrimp (14%), carp (12%) and milkfish (9%) [8, 19, 20]. Catfish output has increased rapidly predominantly because of Vietnam, the top *pangasius* producer in the world. Vietnam's output has increased more than 12-fold since 2000 [8], accounting for 45.8% of regional catfish production in 2014. Farmed shrimp constitutes the highest value of all cultured species. In 2014, shrimp accounted for 31.9% of the total value of all aquaculture output. The value of all farmed

species has steadily increased from 2000 to 2014. Catfish value has risen 18-fold since 2000, versus a 12-fold increase in quantity. Similarly, within the same period, tilapia has shown a 7-fold increment in value. Notwithstanding this strong growth trend, shrimp in the region demonstrated significant fluctuations in value because of disease outbreaks. On the other hand, of a diverse set of landings, mollusks, tuna, mackerel and shrimp accounted for a large portion of capture volume (22.9%) in 2014 (Figure 3B) [8].

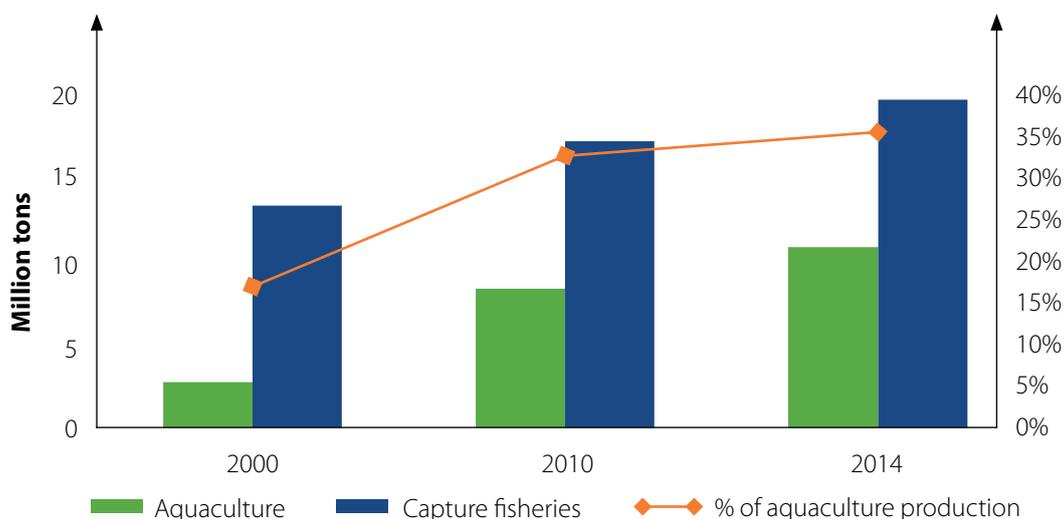


Figure 2. Contribution of aquaculture (excluding aquatic plants) to ASEAN's total fish supply in 2000, 2010 and 2014.

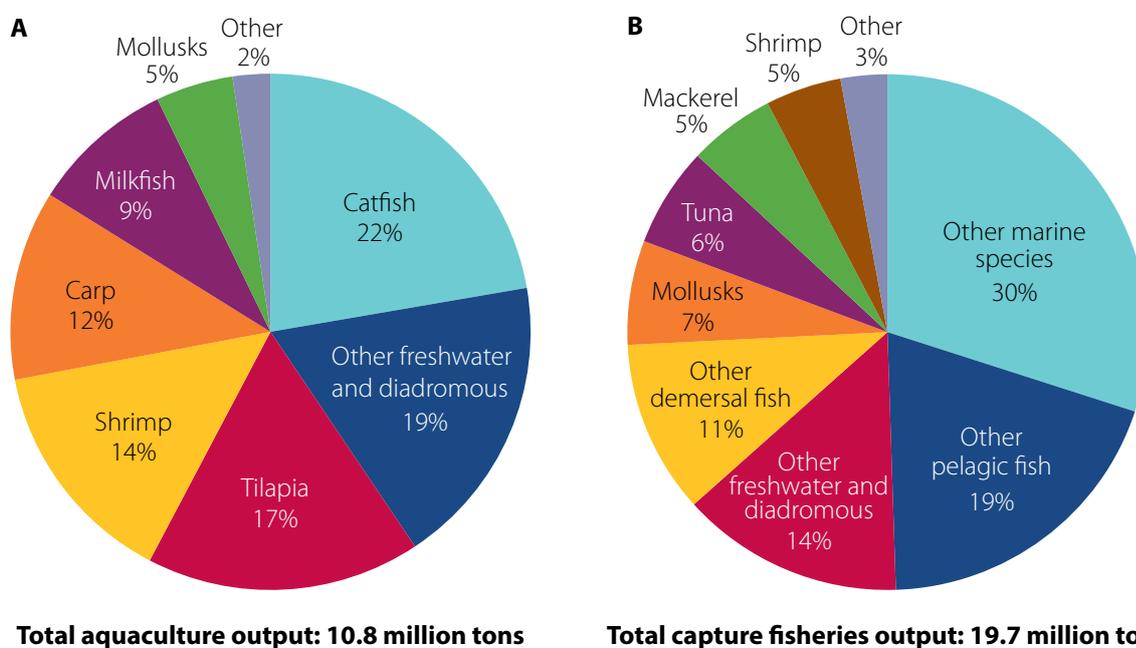


Figure 3. Share of major fish species farmed (A) and wild captured (B) of ASEAN's output in 2014.

Consumption

Food security exists when people have year-round access to sufficient, safe and nutritious food that meets their dietary needs for an active and healthy life [21]. FAO identified poverty as one of the root causes of food insecurity globally [22]. Economically, ASEAN is comprised of high (Brunei, Singapore), upper middle (Malaysia), lower middle (Thailand, Indonesia, the Philippines) and low income countries (Vietnam, Laos, Cambodia, Myanmar) [23, 24]. An estimated 59.6 million people in the ASEAN region are chronically undernourished [25]. Furthermore, other factors such as population growth, urbanization, food price volatility, land acquisition, environmental degradation and climate change are potentially aggravating the multidimensional food insecurity threat in the region [26].

Figure 4 shows that about 95% of the fish supply in the ASEAN region was used for human consumption [8]. Growth in the region's supply of fish for human consumption has outpaced population growth in the past five decades, increasing at an average annual rate of 4.6% from 1961 to 2013, more than double the rate of population growth (2.0%) [8], resulting in increasing average per capita availability.

The ASEAN population relies heavily on fish for food and protein. In 2011, seafood accounted for about 38% of animal protein in the region's diet, followed by meat (33%), milk (20%), eggs (6%) and animal fats and offal (3%) [5]. Table 1 depicts average fish consumption and fish protein intake, as well as the contribution of fish to animal and total protein intake in 2011 [5]. The ASEAN region exhibited a remarkably high per capita fish consumption of 33.4 kg compared to Asia as a whole (21.3 kg) and the lowest of 10.9 kg in Africa. Per capita fish consumption in the region has more than doubled over the past four decades and is now 1.8 times higher than the world average in 2013 (19.2 kg/person/year). Overall, the ASEAN region consumes less animal protein daily per person (24.2 g) than the world average of 31.8 g. However, both the proportion of fish in animal protein intake and in total protein intake is more than double the global average. Fish exceeds half of the animal protein intake in Indonesia and Cambodia. This implies that fish plays a disproportionately important role for food security and nutrition in this region of low animal protein consumption, where fish is often a cheaper and more accessible animal-source food [27, 28]. Other than protein, the main contribution of fish to food and nutrition security is its lipid, micronutrients (fatty acid and vitamins A, B and D) and minerals (calcium, phosphorus, iodine, zinc, iron and selenium) [10, 29-32], which are crucial for combating malnutrition in low-income ASEAN countries.

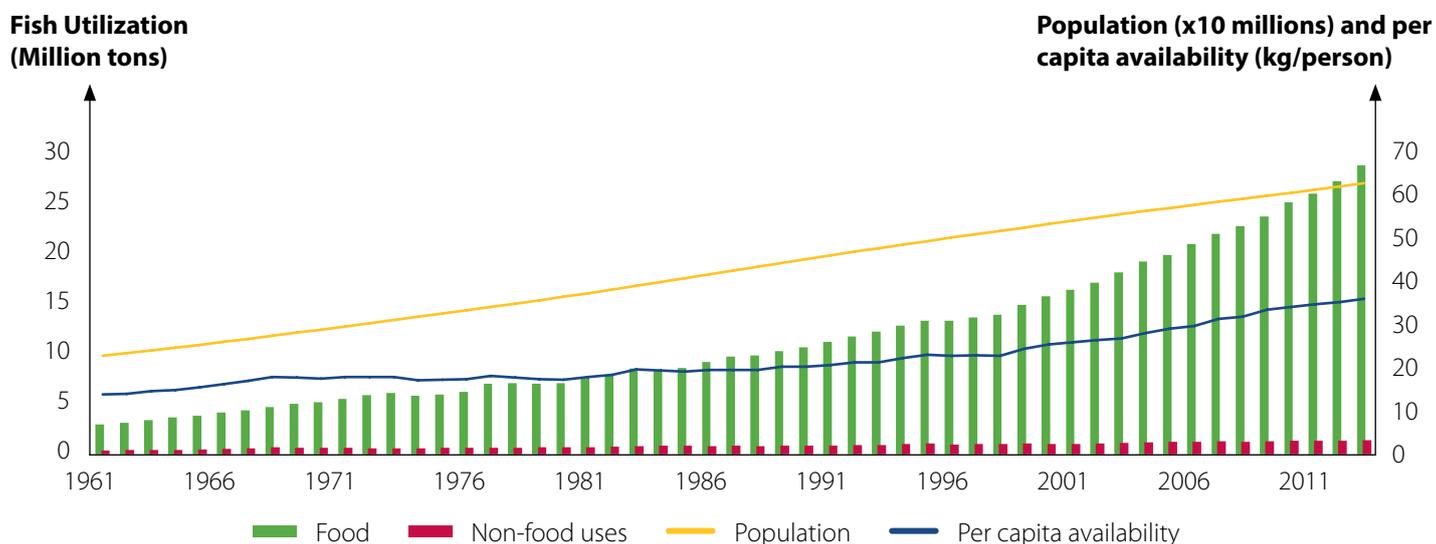


Figure 4. ASEAN fish utilization and supply, 1961–2013.

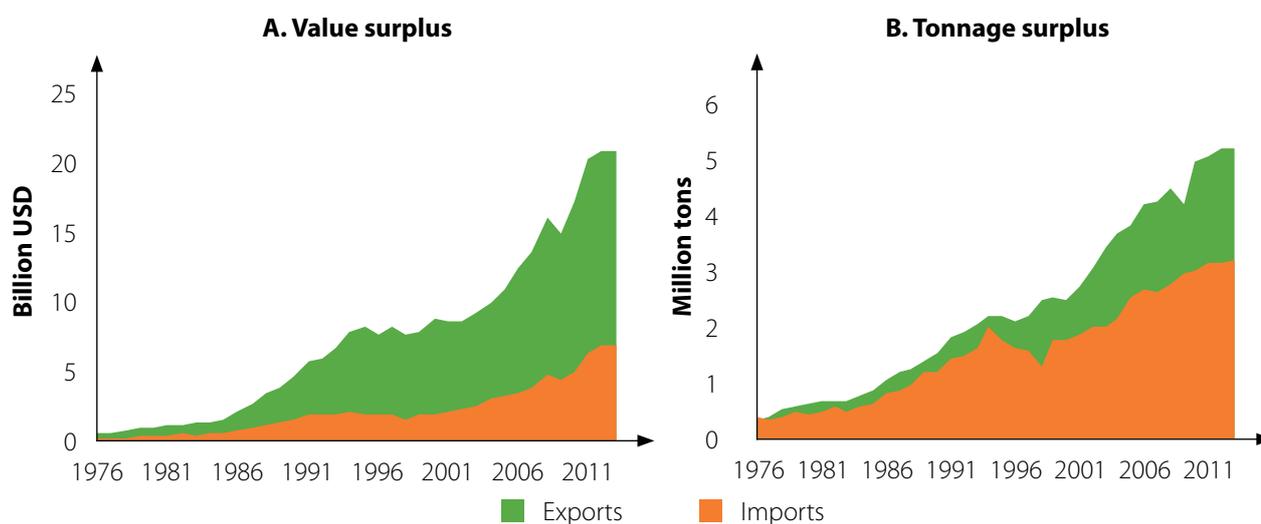
Trade

The fish trade in the ASEAN region has grown dramatically in value, with aggregate exports increasing from USD 0.5 billion in 1976 to USD 20.8 billion in 2013 at an average annual of 11% in nominal terms and 7% in real terms [8]. This region was responsible for 15.1% of global fish exports (USD 20.8 billion) and 5.2% of global fish imports (USD 6.9 billion) in 2013 [8]. Improved long-distance refrigeration, transport infrastructure and faster communications have all contributed to this vast expansion of trade.

Fish trade generally stimulates regional economic growth and development. However, due to the Asian financial crisis in 1997, regional exports and imports dropped 5.4% and 21.2% respectively in 1998 compared with 1997 [8]. A similar trend occurred during the global economic crisis in 2008 when regional exports and imports decreased by 6.9% and 7.9% in 2009 compared with 2008 [8]. Among the

top five fish exporters in the world in 2014, Vietnam became the third biggest exporter (USD 8.0 billion), overtaking Thailand (USD 6.6 billion), which has experienced a substantial decline in exports since 2013. This is mainly linked to reduced shrimp production because of disease outbreaks. Thailand exports further declined in 2015 primarily because of its reduced shrimp production and lower prices of shrimp and tuna [7].

Overall, the ASEAN region has become a net fish exporter. From 1976 to 2011, it showed a gradually increasing surplus of both value and tonnage (Figure 5), and in 2013 it had a surplus of USD 13.9 billion and 2 million tons in fish seafood trade [8]. Malaysia, the Philippines, Laos and Singapore are net fish importers in this region. However, the seafood trade deficits of these countries were more than offset by large surpluses in Indonesia, Vietnam, Myanmar, Thailand and Cambodia.



* Net trade represents total exports minus total imports.

Figure 5. ASEAN net surplus of fish value (A) and tonnage (B), 1976–2013.

Countries	Population (million)	Under-nourished (%)	Fish consumption (kg/person/year)	Fish protein (g/person/year)	Animal protein (g/person/day)	Fish/animal protein (%)	Fish/total protein (%)
Cambodia	14.6	17.0	35.5	11.3	17.8	63.4	17.9
Indonesia	244.8	13.5	28.9	9.6	17.4	54.8	35.4
Laos	6.4	22.8	16.6	5.0	13.2	37.6	27.3
Malaysia	28.6	<5.0	58.1	16.8	43.1	39.0	28.0
Myanmar	52.1	20.2	55.3	14.5	34.1	42.6	29.9
Philippines	94.5	13.0	32.7	9.7	25.0	38.7	27.9
Thailand	66.9	9.3	25.0	8.4	24.2	34.7	25.8
Vietnam	87.8	14.5	33.3	8.6	31.8	27.2	21.4
ASEAN region	595.7	13.2	33.5	10.1	24.2	41.7	15.2
World	7,007.4	12.1	18.9	5.2	31.8	16.4	6.5

* Brunei and Singapore are excluded due to data unavailability [5].

Table 1. ASEAN's average per capita fish consumption and fish, animal and total protein intake 2011.

Methods

The IMPACT model was first used by Delgado et al [33] to produce projections of global food fish production, consumption and trade from 1997 to 2020. This was also the first time that fish was included in a major global agricultural production and trade model. Approximately 10 years after the publication of the *Fish to 2020* report (2003) by IFPRI and WorldFish [33], a follow-up study was commissioned by the World Bank in collaboration with the IMPACT modeling team at IFPRI, the Fisheries and Aquaculture Department of the FAO and the University of Arkansas at Pine Bluff. Incorporating the lessons learned in *Fish to 2020*, a new fish module of the IMPACT model was developed and used to create the *Fish to 2030* report in 2013 [13] covering 2000–2030. *Fish to 2030* also incorporated new developments in global seafood markets and the aquaculture sector. Whereas *Fish to 2020* used a fish species aggregation model based on market characteristics from the consumer perspective, the new model used aggregation primarily based on production systems, feeding regimes and fish diets. The disaggregation is aimed at better reflecting the rising role of fish farming and the resulting closer linkages between fish and agricultural markets. These linkages operate through feed markets, where the livestock and fish farming sectors compete for marine ingredients that are also used in livestock feed. At the same time,

the livestock and aquaculture sectors compete for agriculturally produced, plant-based feeds, which are now major inputs in aquaculture production.

The increasingly important linkages between agricultural and fish sectors, and the increasing role of fish farming versus capture fisheries, also provide justification for conducting an analysis of the seafood markets using economic modeling tools such as the IMPACT model. Aquaculture production can readily be modeled as a farming activity, and agriculture and aquaculture are now linked more closely than ever. The model differentiates capture and aquaculture production of 16 fish commodities (Table 2) and two fish products (fishmeal and fish oil) in 115 regions. At the time of writing, the lack of disaggregate data required that trade and consumption be modeled at a more aggregate level of just nine fish commodities. Part of the reason for the lack of reliable data is the rapid growth of aquaculture species such as tilapia and *pangasius*, which only became prevalent worldwide relatively recently and thus lack a sufficient historical dataset. Another reason is that the data collection streams for FAO databases differ between the domains of production, trade and consumption. Even so, the IMPACT model used here remains the global agricultural and fish model with the highest level of fish commodity detail.

Production fish commodities	Description
Shrimp	Shrimp and prawns
Crustaceans	Aggregate of all other crustaceans
Mollusks	Aggregate of mollusks and other invertebrates
Salmon	Salmon, trout and other salmonids
Tuna	Tuna
Tilapia	Tilapia and other cichlids
<i>Pangasius</i> and other catfish	<i>Pangasius</i> and other catfish
Carp	Major carp and milkfish species
Other carp	Silver, bighead and grass carp
Eel and Sturgeon	Aggregate of eels and sturgeon
Other freshwater and diadromous	Aggregate of other freshwater and diadromous species
Major demersals	Major demersal fish
Mullet	Mullet
Cobia and swordfish	Aggregate of cobia and swordfish
Other pelagics	Other pelagic species
Other marine	Other marine animals

Source: *Fish to 2030* report [13]

Table 2. Sixteen fish production commodity groupings in the IMPACT fish model.

IMPACT is a recursive-dynamic model [34] that finds a global market equilibrium in each year and continues solving sequentially over the projection time horizon. The solution for a given period is based on the solution for the previous period, without foresight, price expectations, stock holding or speculation. As such, this type of model is suited for analyzing alternative sets of long-term equilibria rather than short-term market fluctuations. For each commodity market, the model reaches equilibrium by solving for a single, market-clearing world price that balances global net trade across all regions. At the country level, the supply and demand of each commodity adjust according to price movements where the adjustment is regulated by commodity-specific price elasticities of supply and demand, and there can be either a net trade surplus or deficit, which is to be reconciled on the global market through international trade.

The model begins its projections in 2000 and carries forward to 2050. To introduce dynamics, the IMPACT model incorporates exogenously specified trends in the drivers of change for demand and supply. Key exogenous drivers of demand are per capita income and population growth such that per capita demand, endogenously regulated by price and income elasticities, is scaled each year according to projected income and population levels. Exogenous drivers on the supply side represent productivity and efficiency gains in agricultural production, essentially shifting the intercepts of the supply curves over time. In contrast, supply changes in response to price changes are treated endogenously in the model using supply functions, which embed price elasticities. In this study, exogenous trends are the only determinants of supply growth in capture fisheries production, while the growth of aquaculture supply is regulated by both endogenous price responses and exogenous trends in production and efficiency surrounding feed and feeding practices [13, 35].

Data and model update

The latest available FAO historical production data of fisheries and aquaculture from 2000 to 2013 was reviewed and disaggregated into fish species groupings according to the IMPACT fish model used to generate the *Fish to 2030* report. Historical data was then compared with model projections to ensure that model solutions replicate observed trends for the 2000–2013 period. This time period effectively serves as a calibration tool for the model parameters and a validation tool for verifying the model's ability to accurately represent reality. The current updating effort focuses on ASEAN members and the top aquaculture and capture fisheries producing countries in 2013. A total of 18 model regions

were identified: Bangladesh, Cambodia and Laos, Chile, China, India, Indonesia, Japan, Korea, Malaysia, Mexico, Myanmar, the Philippines, Russia, Scandinavia (Denmark, Finland, Norway and Sweden), Singapore, Thailand, the United States and Vietnam. Overall, these countries accounted for 91.6% of global aquaculture production and 66.8% of global capture fisheries production in 2013 and are the primary drivers of underlying global trends with the substantial share of global output (Table 3).

From the supply side, fish production data was compiled by the Statistics and Information Branch, Fisheries and Aquaculture Statistics and Information Branch (FIPS) of the FAO Fisheries and Aquaculture Department [8]. The data series available in the FishStatJ software [8] include primary production by systems (aquaculture and capture), which are highly disaggregated by fish species (over 2000 species or groups of species). The International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP) was used to ensure consistency of our fish species groupings of the historical production data from 2011 to 2013 with those disaggregated in the *Fish to 2030* report [13].

After validation of production data from 2011 to 2013, fish production growth rates of the ASEAN region and top producer countries worldwide from 2010 to 2015 were calculated using a compound annual growth rate based on three-year moving averages and used to update the model assumptions for the 2010–2015 period. To ensure that the projected trajectory replicated the observed trend between 2000 and 2013, a major effort was made to test, calibrate and review the growth rate to sufficiently match global and ASEAN trends. Calibration was implemented by sequentially and manually fine-tuning model parameters, rather than using an algorithm to calibrate all parameters at once. In this study, all simulations were initiated in the base year of 2000. To evaluate the quality of projections, the model results for aquaculture, capture fisheries and total fish outputs, under the business-as-usual scenario, were compared against the observed production data for 2000–2013 globally and for the ASEAN region. The projected growth rates were extended from 2014 to 2050 using fitted logistic functions.

The final step in the model update was to adjust parameter values so that subsequent model projections were sufficiently close to the historical production data for the calibration period (2000–2013). The results showed that the previous *Fish to 2030* model projections closely followed the global fisheries and aquaculture statistics from 2000 to 2009. However,

because 2009 was the latest year that had historical data at the time of writing of the *Fish to 2030* report, the model projections and the latest historical data start exhibiting discrepancies from 2010 to 2013. In the ASEAN region, aquaculture and capture fisheries growth was underestimated from 2000 to 2013. This provides valid justification for the need to update IMPACT model fish parameters by the team of experts at WorldFish, as this type of exercise requires detailed knowledge of trends and structural changes in the region, industry and policy. Appendix A compares the *Fish to 2030* and updated *Fish to 2050* projections of global and ASEAN capture and aquaculture production with the actual data over the 2000–2013 period. The updated parameters were calibrated to minimize the difference between the projections and the actual data, even more so than the previous *Fish to 2030* projections, both at the global and ASEAN-regional level.

After the calibration to historical trends up to 2013, the production growth rates for capture fisheries and aquaculture were further adjusted by country and fish commodity based on the observed trends and extrapolated from 2014 to 2050. These calibration attempts take into account national fisheries and

aquaculture targets, as well as the biological resource growth potentials and constraints.

A stakeholder consultation workshop was conducted in June 2016 in Penang to collect further data and information as well as expert inputs from individual ASEAN countries. The workshop details are presented in Appendix B. Calibration of the projected aquaculture and capture fisheries in eight ASEAN countries to 2050 is illustrated in Appendixes C and D. A revised projection was made taking into account the inputs and comments from the stakeholder consultation for individual countries at the fish species-level, according to national government targets and a country-level understanding of maximum carrying capacities. For aquaculture production, almost all countries have optimistic expectations of higher output until 2050. The exceptions are Vietnam, Indonesia and Thailand, which remain the same as the original projections (Appendix C). Indonesia, the Philippines and Malaysia expect to increase their capture fisheries production compared to previous model projections, while Vietnam expects lower total output. The remaining countries are consistent with the original projections (Appendix D).

Countries	Rank	Output (thousand tons)			Share of world output (%)		
		Capture	Aquaculture	Total	Capture	Aquaculture	Total
Bangladesh	9	1,550	1,860	3,410	1.7	2.6	2.1
*Cambodia & Laos		674	198	872	0.7	0.3	0.5
Chile	13	1,771	1,033	2,804	1.9	1.5	1.7
China	1	16,275	43,552	59,827	17.6	62.0	36.7
India	3	4,645	4,550	9,195	5.0	6.5	5.6
Indonesia	2	6,103	3,849	9,952	6.6	5.5	6.1
Japan	8	3,657	609	4,266	3.9	0.9	2.6
Korea	14	1,598	402	2,000	1.7	0.6	1.2
Malaysia	16	1,489	261	1,750	1.6	0.4	1.1
Mexico	15	1,627	169	1,796	1.8	0.2	1.1
Myanmar	6	3,787	929	4,716	4.1	1.3	2.9
Philippines	11	2,335	815	3,150	2.5	1.2	1.9
Russia	7	4,346	155	4,501	4.7	0.2	2.8
Scandinavia	10	2,074	1,248	3,322	2.2	1.8	2.0
Singapore		2	5	7	0.0	0.0	0.0
Thailand	12	1,844	1,057	2,901	2.0	1.5	1.8
United States	4	5,231	441	8,573	5.6	0.6	5.3
Vietnam	5	2,804	3,207	6,011	3.0	4.6	3.7
Total		61,811	64,340	126,151	66.8	91.6	77.5
ASEAN region		19,036	10,322	29,358	20.6	14.7	18.0
World		92,582	70,224	162,806	100.0	100.0	100.0

* Cambodia and Laos are combined into one region in the IMPACT model.

Brunei is included in an aggregate region, but not modeled separately in the IMPACT model due to its small agricultural footprint and a lack of data.

Table 3. Aquaculture and capture fisheries output among ASEAN members and top producer countries worldwide, 2013.

Results

Future trends of fish in the ASEAN region

The business-as-usual scenario in this study is characterized by a set of model parameters that were considered to reflect the past trends that will continue into the future. These trends take into account knowledge from published sources and regional experts, along with feedback from stakeholder consultation on national government targets and the maximum carrying capacity of the sector. They also need to be consistent with the expected changes in the future. These projected results should not be considered as forecasts, but rather as a benchmark for exploring plausible future scenarios on how this sector will evolve until 2050, taking into account assumptions on the biophysical, socioeconomic and technological factors influencing future fish production, consumption and trade at the global and regional level. This paper focuses on the business-as-usual scenario analysis. Further analysis on other alternative scenarios, such as the impact of climate change on capture fisheries and aquaculture production, will be emphasized in a follow-up publication.

Business-as-usual projection

Production

Table 5 lists the key projections for the business-as-usual scenario of fish production, net trade and consumption in the ASEAN region from 2015 to 2050. The projections describe plausible future trends for the fisheries and aquaculture sectors in the next 35 years. Overall, slower growth is projected for production, consumption and net trade from 2030 to 2050 (second phase) compared with that from 2015 to 2030 (first phase).

Total fish production in the ASEAN region is likely to expand at about 2.9% annually in the first phase and 0.2% annually in the second phase, reaching 54.2 million tons in 2050. The total output of aquaculture is projected to double from 13.3 million tons in 2015 to 26.7 million tons in 2050. This will occur at an

average annual growth rate of 4.2% in the first phase and then slow to 0.5% in the second. The absolute growth is projected to be 14.1 million tons from 2015 to 2050, the majority of which will be from Indonesia (8.6 million tons) and the Philippines (1.8 million tons). On the other hand, capture fisheries production will rise 1.8% annually in the first phase and then remain stagnant at 26.8 million tons from 2030 onwards. Despite the relatively faster rate of expansion of aquaculture, capture fisheries will remain the dominant source of fish supply in the ASEAN region until 2050 when it will approximately equal aquaculture production (Figure 6B), whereas the global production of fisheries and aquaculture will be approximately equal by 2030 (Figure 6A) due to the relative production trends. Nonetheless, the share of aquaculture output in the region will rise from 36% in 2014 to 48% in 2030 and then reach slightly more than half of the total production by 2050 (Figure 7A). The ASEAN region's share of total global fish supply is estimated to increase from 18.9% in 2015 to 23.8% in 2030 (Table 4). Aquaculture will increase to a sizable share of 22%, while capture fisheries will reach more than a quarter of the global output in 2030. The share is expected to drop slightly for aquaculture, but remain the same for capture fisheries in the second phase of the projection in 2050 (Table 4).

Freshwater species, such as *pangasius* and other catfish, carp and tilapia, are expected to remain the major sources, by tonnage, of aquaculture output. These three commodity groups, combined, are projected to increase in annual growth from 4.3% to 5.3% in the next 15 years. They represent 62.6% of all aquaculture production in the ASEAN region in 2015 and will continue to increase slightly to 68.9% by 2030 and then gradually decline to 66.2% by 2050. However, high value species such as shrimp are estimated to grow in terms of the share of total tonnage of aquaculture production from 14.8% in 2015 to 16.9% by 2050. In 2015, Indonesia and Vietnam were the top regional farmed shrimp producers, with a 43.2%

Production	Share of global production (%)		
	2015	2030	2050
Aquaculture	16.4	22.0	19.6
Capture fisheries	20.9	25.8	25.8
Total fish	18.9	23.8	22.3

Table 4. ASEAN's share of global production in 2015, 2030 and 2050.

and 31.7% share of the total regional farmed shrimp output, respectively. This trend is likely to continue through out the entire projection period.

Among the diverse set of landings in capture fisheries, tuna is expected to have the highest annual growth rate (by tonnage) at 5.8% in the first phase. Tuna and shrimp shares of total landings were 6.5% and 4.3% in 2015. The biggest producer of tuna and shrimp from capture fisheries is Indonesia, which will contribute 2.5 million tons (81%) of tuna production and 2.2 million tons (45%) of shrimp output in 2030. However, the largest share of the fish landings from the “other marine” fish group will experience a reduction in output throughout the first phase, declining 0.3% annually.

Consumption

According to OECD-FAO Agricultural Outlook [9], capture fisheries for human consumption refer to capture production that excludes ornamental fish and fish destined for the production of fishmeal, fish oil and other non-food uses. All aquaculture production is assumed to be destined for human consumption [9]. Figure 6B depicts that approximately 97% of fish in the ASEAN region are projected to be utilized for human consumption during the simulation period. A new milestone was achieved in 2014 when global aquaculture contributed more than half of the fish supply for human consumption. In the ASEAN region, this milestone is expected to be met by 2033. Above all, aquaculture in the region is expected to further increase its share of the total fish supply for human consumption to 52% (27.4 million tons) in 2050 (Figure 7B).

Fish consumption in the ASEAN region is projected to rise from 24.5 million tons in 2015 to 36.9 million tons in 2030 and then reach 47.1 million tons in 2050, while per capita fish consumption is expected to increase from 38.4 kg in 2015 to 51.5 kg in 2030 and then 61.5 kg in 2050. Similar to the production growth trend, per capita fish consumption increases 2.0% annually in the first phase then grows at a slower pace (0.9%) in the second phase (Table 5). In spite of the increased availability of fish for food, the rise of per capita fish consumption will not be uniform among ASEAN countries. The Philippines, Myanmar, Cambodia and Laos are at or below the projected average per capita fish consumption in the region over the simulation period. Throughout the projection period, the region’s population is expected to consume about 50 g of fish oil per person annually, which is more than double the average world per capita consumption of about 22 g.

Estimates of the nutrient composition of consumed portions of different fish species were obtained by connecting IMPACT’s modeled fish with the United States Department of Agriculture (USDA) food composition databases [36]. Higher per capita fish and fish oil consumption suggests that the potential nutrients from fish consumption available to the population are also expected to grow. On a per capita basis, the increase in protein, energy, lipid, vitamin and mineral intake from fish consumption is expected to rise to between 2.3% and 3.6% from 2015 to 2030 and then slightly decline to between 0.6% and 1.4% annually from 2030 to 2050 (Table 5).

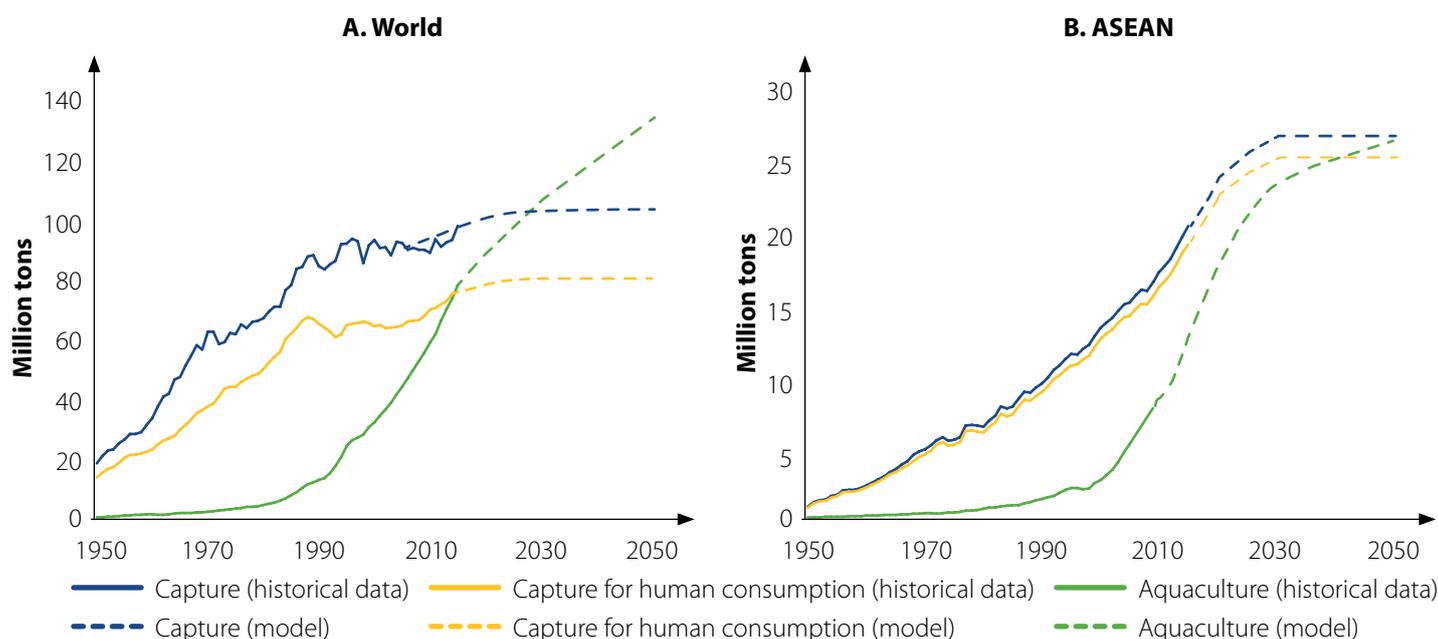


Figure 6. Global (A) and ASEAN (B) capture fisheries and aquaculture production (excluding aquatic plants), 1950–2050.

Trade and Prices

International net trade of fish in the ASEAN region is expected to expand at 3.7% annually from 2015 to 2030 and then decline by 5.4% per year from 2030 to 2050. In addition, net trade of fish is also estimated to rise from 6.3 million tons in 2015 to 11 million tons in 2030 and then to drop to 3.6 million tons in 2050 (Table 4). All aggregate fish species in the model, except salmon and mollusks, are estimated to have surpluses for export throughout the simulation period.

Figure 8 shows the historical (2000–2014) and projected (2015–2050) global aquaculture and capture fisheries prices in real terms. From 2000 to 2014, the global aquaculture price grew faster than capture fisheries (0.9% versus 0.3% per year, respectively) reaching USD 2059 per ton for aquaculture and USD 1463 per ton for capture fisheries. Using an estimation by the FAO Fish Price Index [11], although the real prices of farmed fish are higher than wild species, their prices are likely to increase and may reduce the gap significantly by 2050. The model projects that the real prices of all fish species will increase during the projection period.

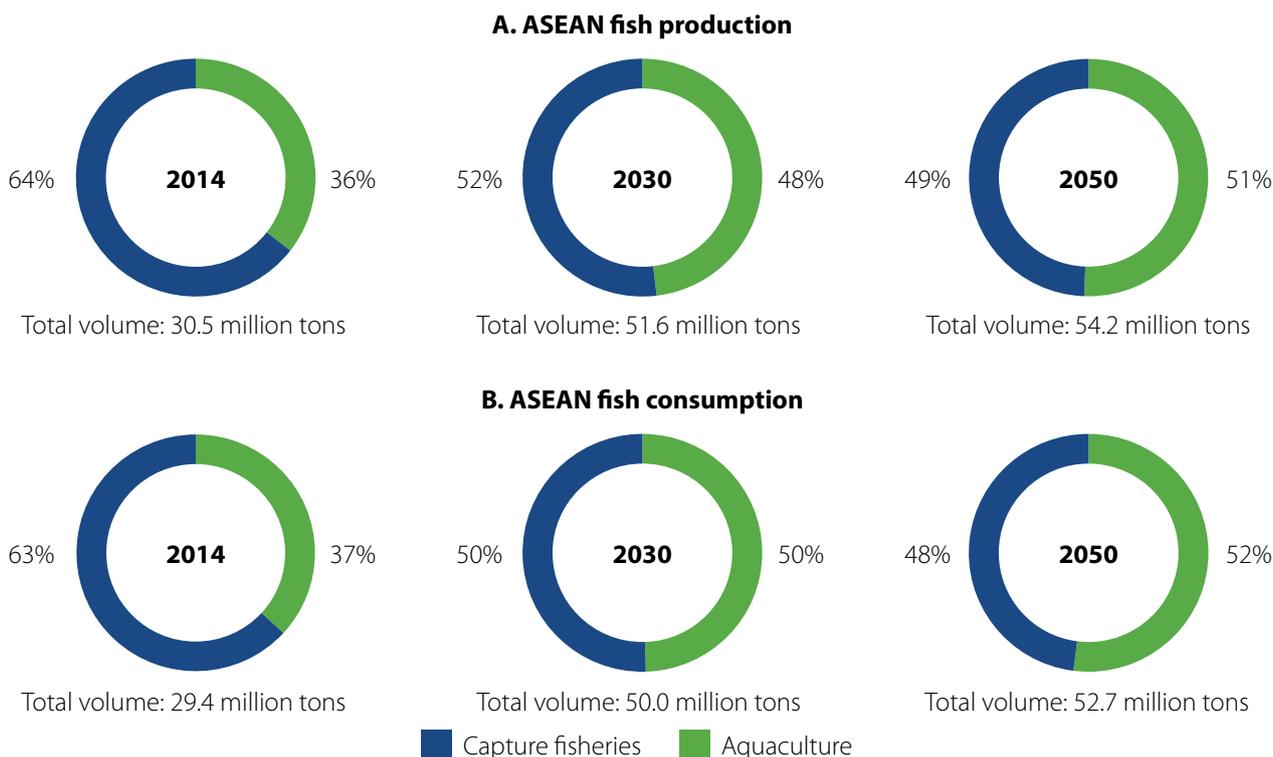
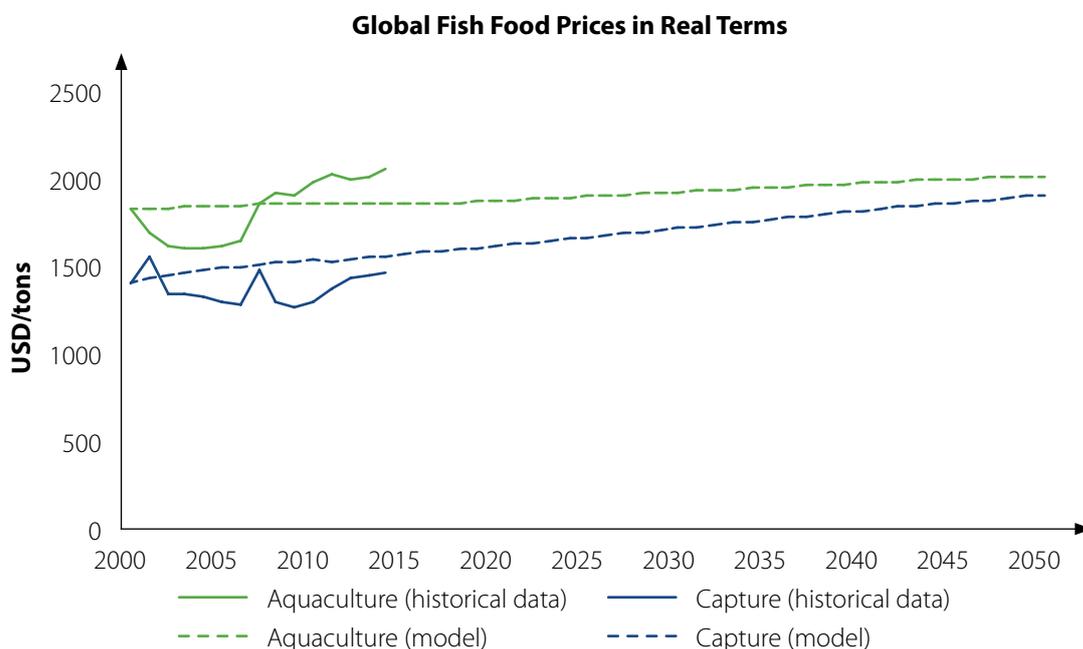


Figure 7. Relative shares of capture fisheries and aquaculture in ASEAN fish production (A) and fish consumption (B) in 2014, 2030 and 2050.



Historical data source: OECD [9] and FAO [11]

Figure 8. Projected global fish prices in real terms, 2000–2050.

Item	Year								Average annual growth	Average annual growth
	2015	2020	2025	2030	2035	2040	2045	2050	(2015–2030, %)	(2030–2050, %)
	thousand tons									
Total fish production	33,298.7	41,662.7	46,918.7	50,313.9	51,287.8	52,032.9	52,592.7	53,301.6	2.8	0.3
Aquaculture production	13,292.6	18,387.7	22,241.8	24,793.1	25,921.4	26,658.3	27,055.0	27,400.2	4.2	0.5
Carp	2,596.6	3,959.1	4,914.1	5,636.8	5,825.0	5,887.4	5,914.8	5,921.5	5.3	0.2
Crustacean	107.5	121.8	127.3	130.6	133.7	136.5	134.0	131.6	1.3	0.0
Major demersals	54.4	67.0	81.0	95.1	109.2	123.6	138.1	152.7	3.8	2.4
Mollusks	480.4	649.2	1,019.2	1,003.0	963.2	986.1	972.4	960.9	5	-0.2
Mullet	10.6	12.4	14.2	16.1	18.3	20.7	23.0	25.5	2.8	2.3
Other carp	84.5	86.6	93.0	96.2	97.2	97.8	98.2	98.5	0.9	0.1
Other freshwater and diadromous	1,879.6	2,014.3	2,003.1	2,078.9	2,339.5	2,573.7	2,710.9	2,838.6	0.7	1.6
Other marine	386.8	436.6	447.8	435.9	437.1	438.0	408.0	426.7	0.8	-0.1
<i>Pangasius</i> and other catfish	3,320.5	4,780.7	5,564.3	6,272.0	6,517.8	6,564.2	6,556.1	6,533.8	4.3	0.2
Shrimp	1,962.8	2,659.6	3,360.7	3,851.8	4,133.5	4,343.4	4,508.2	4,634.9	4.6	0.9
Tilapia	2,409.0	3,600.3	4,617.3	5,176.8	5,346.9	5,486.9	5,591.3	5,675.4	5.2	0.5
Capture production	20,481.1	23,956.7	25,626.9	26,757.5	26,770.7	26,791.9	26,751.1	26,767.8	1.8	0.0
Shrimp	890.0	945.3	977.9	1,002.3	1,002.3	1,002.3	1,001.6	1,001.1	0.8	0.0
Crustacean	303.2	365.4	430.0	495.6	495.2	494.9	494.7	494.5	3.3	0.0
Mollusks	1,351.0	1,456.9	1,511.9	1,550.6	1,548.4	1,548.1	1,548.3	1,548.7	0.9	0.0
Major demersals	2,245.1	3,705.9	4,099.4	4,337.8	4,348.7	4,355.5	4,362.9	4,369.4	4.5	0.0
Tuna	1,327.2	2,195.0	2,755.1	3,076.3	3,062.3	3,058.1	3,056.9	3,056.5	5.8	0.0
Cobia and swordfish	17.1	18.1	19.2	20.5	20.5	20.5	20.5	20.5	1.2	0.0
Eel and sturgeon	6.4	7.3	8.3	9.6	9.6	9.6	9.7	9.7	2.8	0.1
Tilapia	129.5	144.0	155.8	167.7	169.4	170.9	172.3	173.6	1.7	0.2
<i>Pangasius</i> and other catfish	124.6	163.0	178.4	184.5	183.1	182.7	182.6	182.6	2.6	-0.1
Carp	24.1	26.8	28.2	29.1	29.2	29.2	29.3	29.3	1.3	0.0
Mullet	82.0	99.3	106.8	111.0	110.2	109.8	109.6	109.4	2.0	-0.1
Other freshwater and diadromous	3,060.1	3,168.6	3,221.7	3,255.7	3,263.4	3,269.2	3,273.7	3,277.1	0.4	0.0
Other pelagics	4,652.5	5,534.7	6,116.0	6,555.2	6,555.1	6,554.9	6,533.9	6,534.1	2.3	0.0
Other marine	6,268.1	6,126.5	6,018.1	5,961.7	5,973.3	5,986.1	5,955.3	5,961.5	-0.3	0.0
Shrimp	890.0	945.3	977.9	1,002.3	1,002.3	1,002.3	1,001.6	1,001.1	0.8	0.0
Net Trade	6,348.2	10,173.3	11,463.7	10,982.6	8,341.0	5,793.6	4,426.1	3,648.9	3.7	-5.4
	kilogram/person/year									
Per capita consumption	38.4	43.1	47.3	51.5	55.5	58.9	60.5	61.5	2.0	0.9
Nutrients from fish consumption	milligram/person/day									
Protein	198.8	238.8	276.7	316.8	354.8	394.1	411.0	425.8	3.2	1.5
Energy, Kcal	1,403.4	1,679.6	1,942.7	2,221.1	2,485.4	2,758.1	2,874.7	2,976.4	3.1	1.5
Total lipid (fat)	60.4	71.9	82.9	94.7	105.9	117.4	122.3	126.5	3.0	1.5
<i>Lipids</i>										
Saturated fatty acids	13.7	16.2	18.6	21.3	23.8	26.4	27.5	28.5	3.0	1.5
Monosaturated fatty acids	22.4	26.7	31.0	35.5	39.8	44.3	46.3	48.0	3.1	1.5

Item	Year								Average annual growth	Average annual growth
	2015	2020	2025	2030	2035	2040	2045	2050	(2015–2030, %)	(2030–2050, %)
Polysaturated fatty acids	15.7	18.7	21.6	24.6	27.5	30.4	31.5	32.6	3.0	1.4
Cholesterol	722.9	871.6	1,014.1	1,163.7	1,305.1	1,450.8	1,514.7	1,570.9	3.2	1.5
<i>Vitamins</i>										
Vitamin A	1,509.7	1,850.7	2,186.1	2,546.0	2,898.7	3,264.2	3,437.7	3,591.7	3.5	1.7
Vitamin B6	3.2	3.8	4.5	5.1	5.6	6.2	6.4	6.6	3.2	1.3
Vitamin B12	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.07	2.3	1.0
Vitamin C	6.1	7.3	8.5	9.7	10.9	12.2	12.7	13.3	3.2	1.6
Vitamin D	2.6	3.2	3.8	4.4	5.1	5.8	6.1	6.4	3.6	1.9
Vitamin E	7.2	8.4	9.5	10.6	11.7	12.8	13.3	13.6	2.6	1.3
Thiamin	1.1	1.3	1.5	1.7	2.0	2.2	2.3	2.3	3.3	1.5
Riboflavin	1.6	1.9	2.1	2.4	2.6	2.8	2.9	2.9	2.7	1.1
Niacin	59.9	71.0	81.4	92.4	102.6	113.1	117.4	121.0	2.9	1.4
Folate	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	3.7	1.7
<i>Minerals</i>										
Calcium (Ca)	442.0	512.7	579.5	649.7	715.9	783.6	809.2	831.2	2.6	1.2
Iron (Fe)	11.6	13.4	15.1	16.9	18.5	20.2	20.8	21.3	2.5	1.2
Phosphorus (P)	2,572.3	3,108.5	3,622.0	4,165.4	4,686.4	5,224.1	5,463.7	5,674.0	3.3	1.6
Zinc (Zn)	11.6	13.8	15.9	18.1	20.1	22.2	23.1	23.9	3.0	1.4
Magnesium (Mg)	374.2	440.3	502.3	567.5	629.1	692.3	717.6	739.3	2.8	1.3
Potassium (K)	3,577.1	4,297.4	4,973.9	5,685.2	6,355.1	7,046.2	7,338.9	7,593.1	3.1	1.5
Sodium (Na)	1,548.0	1,845.2	2,127.6	2,408.0	2,667.8	2,928.5	3,039.9	3,136.8	3.0	1.3

Table 5. ASEAN's projected growth of fish production, trade, consumption and nutrients 2015–2050.

Discussion

Model projections are results of complex interactions among commodity groups and countries across the regions. Under the business-as-usual scenario, several salient findings are projected. Fish production in the ASEAN region will likely grow faster than the regional population growth. Consequently, people in the region will benefit from fish food and nutrition via increasing per capita fish consumption. In absolute volume, fish production in the ASEAN region is projected to grow and reach nearly a quarter share of the global fish output, by tonnage, in 2030 and will remain at that level until 2050. Per capita fish consumption in the region will likely have tripled from 1980 to 2030, while regional net trade will continue to increase in the first phase of the projection period (2015–2030) but will slowdown in the second phase (2030–2050). It is noted that real prices of wild fish will grow slightly faster than farmed fish.

In past trends, ASEAN countries showed an exceptionally high growth of 7% in aquaculture production over the previous five decades. This growth was from both extensive and intensive production systems [37]. The presence of strong institutional networks in the region have also played an important role in supporting the development of the aquaculture sector. These include the Network of Aquaculture Centers in the Asia-Pacific (NACA), the Southeast Asian Fisheries Development Center (SEAFDEC), the Asian Institute of Technology (AIT) and CGIAR's WorldFish [38]. In the next four decades, aquaculture production will continue to be one of the fastest-growing animal-based food sectors of the ASEAN region's economy with a projected growth rate of 2%. Aquaculture is likely to supply more than half of the fish consumed in the region in the coming decade. *Pangasius* and other catfish, carp and tilapia are projected to remain the major sources of aquaculture output. Capital investment is needed to advance aquaculture technologies to improve efficiency gains and reduce production costs that will increase the competitiveness of farming operations. Relative sluggishness from 2030 to 2050 is projected because of several principal constraints: fish farming in the region reaching near maximum carrying capacity, limited access to quality freshwater, limited availability of quality fish seeds and feeds, competition for land use, fish price volatility, challenges of regional governance and regulation, environmental degradation and climate change.

At the global level, capture fisheries are projected to be stagnant at about 103 million tons annually to 2030. Our analysis showed that ASEAN capture fisheries are still growing (3% annually from 1976 to 2014). This is supported by the fact that coastal waters in the region are among the most productive and biologically diverse in the world [39, 40], although they are significantly at risk from climate change [41]. Capture fisheries are projected to increase 2% annually from 2015 but will likely remain stagnant after 2030. Several factors influence capture fisheries growth in the region, including expansion of the geographical range of fishing activities and an increase in the overall biomass of the fisheries as a result of overfishing long-lived, larger species, benefiting smaller, short-lived species [39]. Capture fisheries are projected to continue to be the dominant source of fish supply in the ASEAN region through to 2050. However, there is a critical role for improved capture fisheries management and governance to sustain fish supply. Rapid population growth and surging food demand are creating tremendous stress on coastal and inshore fishery resources in the region [39]. Fish stocks there are under threat from over depletion due, in part, to overfishing and overcapacity [39, 42-44]. Weak marine governance, socioeconomic uncertainties and ecosystem change can add further uncertainties, which negatively impact future trends of ASEAN capture fisheries. In response to the compelling challenges and emerging issues, existing regional fisheries institutions such as SEAFDEC, the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF), the Illegal, Unregulated, and Unreported Regional Plan of Action (RPOA-IUU), the Asia-Pacific Fishery Commission (APFIC) and Partnerships in the Environmental Management for the Seas of East Asia (PEMSEA) are facing significant workloads to support fisheries management [39]. These efforts need to be strengthened and connected to science- and evidence-based policy analyses for improved management.

On the demand side, per capita consumption in the ASEAN region has doubled from 1980 to 2013 and will likely triple by 2030. While fish is relatively expensive compared to other food commodities, income elasticities of demand for fish are generally high, which indicate that seafood is highly preferred [13, 45]. As a consequence, rising incomes across the region induce a notable increase of fish consumption. The trend of migration to urban areas is projected to increase rapidly in the region by 2050 with the urban

population projected to surpass the rural population by 2020 [1]. Urbanization will contribute to higher fish consumption because it offers a bigger and more comprehensive market, offering a wider choice for consumers and incentives for producers to supply a dense population that can no longer grow food of its own. Consumer food preferences also seem to be shifting from meat toward fish because of the benefits of fish for human nutrition and health, which are well documented [46-51]. Compared to most terrestrial meats, fish has a higher protein content, is leaner on an edible fresh weight basis, has a higher concentration of omega-3 fatty acids and is a richer source of most essential minerals and key water soluble and fat soluble vitamins [32, 36]. Projected higher per capita fish and fish oil consumption will lead to increased nutrition benefits for the ASEAN region.

Fish trade will become a more prominent source of foreign exchange earnings for the ASEAN region. Regional fish and fishery products will continue to be heavily traded in the future, fueled by higher consumption of fish, the removal of regional tariffs and quotas [39], globalization of the food system and improvement in long distance refrigerated transport and large-scale shipments. After a slow but gradual economic recovery from the global economy crisis in 2008, fish exports in the ASEAN region have been revitalized. Currently, Vietnam and Thailand are two of the top five fish exporters globally. By tonnage, shrimp, tuna, catfish and various forms of marine fish are important export species [52]. As the region's population continues to grow and incomes catch up with more developed regions, fish exports may decrease in the second phase of the projections (2030–2050) to meet the domestic demand. Import substitution and the desire to save on foreign exchange are rationales to motivate ASEAN national governments to support aquaculture expansion. In addition, with the development of export-oriented aquaculture, especially in Indonesia and Vietnam, fish surplus in the region will likely be sustained in the near future. Even if exports of seafood do taper off in the later decades, as indicated in the projections, the strong scientific and technological base that spurred the growth of the aquaculture sector might offer an opportunity to export technical know-how and afford investment opportunities for Southeast Asian companies in other regions in the world. On the other hand, due to the pivotal role of aquaculture production, unless cost-effective alternatives to fishmeal and fish oil can be found [53], ASEAN countries, particularly Vietnam and the Philippines, will remain net importers of both until 2050.

During the recent global food price spikes, fish prices grew at a relatively moderate pace to record highs [11, 54]. They were less volatile than those of cereals, dairy and oils, and were thus more competitive than meat. In addition, fish prices are not expected to revert to lower levels from the projections, but will continue to rise as a result of population growth, increased demand and supply constraints. Although aquaculture will help to minimize the gap by stabilizing fish supply, the price of some farmed species tends to be higher than that of capture fisheries, which is comprised of a great volume of small, low-value capture species. Farming herbivorous fish, such as carps in Myanmar (about the same price as small pelagic fish), and milkfish in Indonesia and the Philippines, needs continued emphasis to maintain accessibility to relatively affordable fish products in the region. Both capture fisheries and aquaculture have specific susceptibilities to production volatility from stock fluctuations in fishing and the risk of disease outbreak in aquaculture, but these do not often occur simultaneously. Both sectors have highly complementary roles in ensuring that fish becomes available and affordable to poor consumers in the ASEAN region.

While the fish sector's contribution to regional economic growth has been prioritized, the challenges of environmental degradation, such as mangrove depletion, declining water quality and disease in farmed fish, will provoke tensions between the efforts for sustainable economic growth and ecosystem protection [55, 56]. Furthermore, climate change, variability and extreme weather events are compounding threats to the sustainability of capture fisheries and aquaculture development in marine, brackish and freshwater environments in the region [57]. Climate change will have serious consequences for fishers and fish farmers. Governments' preparedness to mitigate climate change risks and impacts requires a thorough understanding of the sector's vulnerability at the local and national levels. Of the 10 countries worldwide most vulnerable to climate change (in terms of the number of people likely to be affected), four are in the ASEAN region: Vietnam, Cambodia, Thailand and the Philippines [41]. Vietnam is already taking action to select a salinity-tolerant catfish strain to mitigate the climate change risks in the aquaculture sector [58]. Aquaculture in the ASEAN region is dominated by small-scale producers. A strong focus should be on building general adaptive capacity that supports poor and small-scale aquaculture producers and value chain actors to make the most of new opportunities and cope with the challenges related to adverse climate change impacts [59].

Capture fisheries and aquaculture in the ASEAN region are important, therefore policies and priorities should be balanced for maximizing sustainable growth and benefits of both sectors. Various stakeholders, including governments, private sector, consumers, nongovernmental organizations (NGOs) and donor agencies, need to foster cooperation to strengthen strategic partnerships for implementing effective management for sustained growth while mitigating potential impacts on biodiversity and natural resources in the region. Policies to promote sustainable and climate-adaptable aquaculture are crucial and should focus on alternatives such as improved feed and seed production, reduced dependence on imported fishmeal and fish oil, increased investment in durable infrastructure, and strategies to adapt and mitigate climate change impacts [19]. On the other hand, governance in the fisheries sector requires greater adherence to, and enforcement of, existing laws to combat illegal, unreported and unregulated (IUU) fishing activities. There is also a need to increase the understanding of the environmental constraints and options for the various modeled growth scenarios, such as in recent research in Indonesia [56, 60].

Modeling work for generating an evidence base for decision-making is also crucial. While the IMPACT fish model has been greatly improved so that it can generate reasonable fish sector projections at both global and regional levels, the current setup suffers some limitations in terms of data and model structure. Available data is inconsistent and the lack of trade data at the desirable species classification leads to the inability to analyze bilateral trade flows, which makes analysis of specific trade policy difficult without complementary work. Global markets with homogenized commodities is a necessary simplifying assumption that might be more contentious in the seafood market than, for example, in the cereal, meal or oil markets, where products are commoditized to a larger degree. On the other hand, the sheer number of different fish species being caught and farmed requires some form of simplification to be modeled at all. Other potential issues to address in the modeling framework include dealing with climate change and environmental stresses more explicitly, updating the underlying database with the latest available data and embedding the ability to develop new and alternative fisheries where they might not have previously been considered.

The benefits of the structural modeling approach, such as with the IMPACT model, are manifold. Larger-scale modeling work enforces discipline on inconsistent data, either in the form of requiring the maintenance

of basic physical balances or by applying simple laws of economics (supply equals demand, global exports equal global imports, etc.). The modeling efforts expose data inconsistencies that would not become obvious in narrowly focused analyses. The model also exposes important data gaps and identifies the areas where improved data collection is needed. Fisheries and aquaculture are a relatively new realm of analysis using these types of foresight modeling tools, but further refinement will greatly improve their applicability for policymaking. Examples of the successful use of partial-equilibrium models for policy analysis can be found in the IMPACT model's past, as well as with other modeling systems (GLOBIOM, AgLINK-COSIMO, and CAPRI). For future efforts, it is important to advance fish foresight modeling to position fish into global and regional food systems while paying attention to national and subnational foresight modeling needs. This will help national partners in improving fish sector planning, priority setting and policy interventions.

Conclusions

Both aquaculture and capture fisheries production in the ASEAN region will continue to grow. Capture fisheries will remain the dominant fish supply by 2050, and aquaculture will supply more than half of fish consumed in the coming decade. Recognizing the interactions of the growth of both sectors with the regional socioeconomic development of coastal and rural communities, as well as the contribution to

food nutrition and security and the implications for environmental sustainability, the focus of regional policies should not only be to promote aquaculture expansion, but also to strengthen regional fisheries governance and management. Future effort to enhance national data sharing and improve model structure development will provide a better foresight modeling tool for fish sector policy formulations.



Photo credit: Chien-Li-Pou, Bingyi, Weidong

ASEAN workshop group in Penang.

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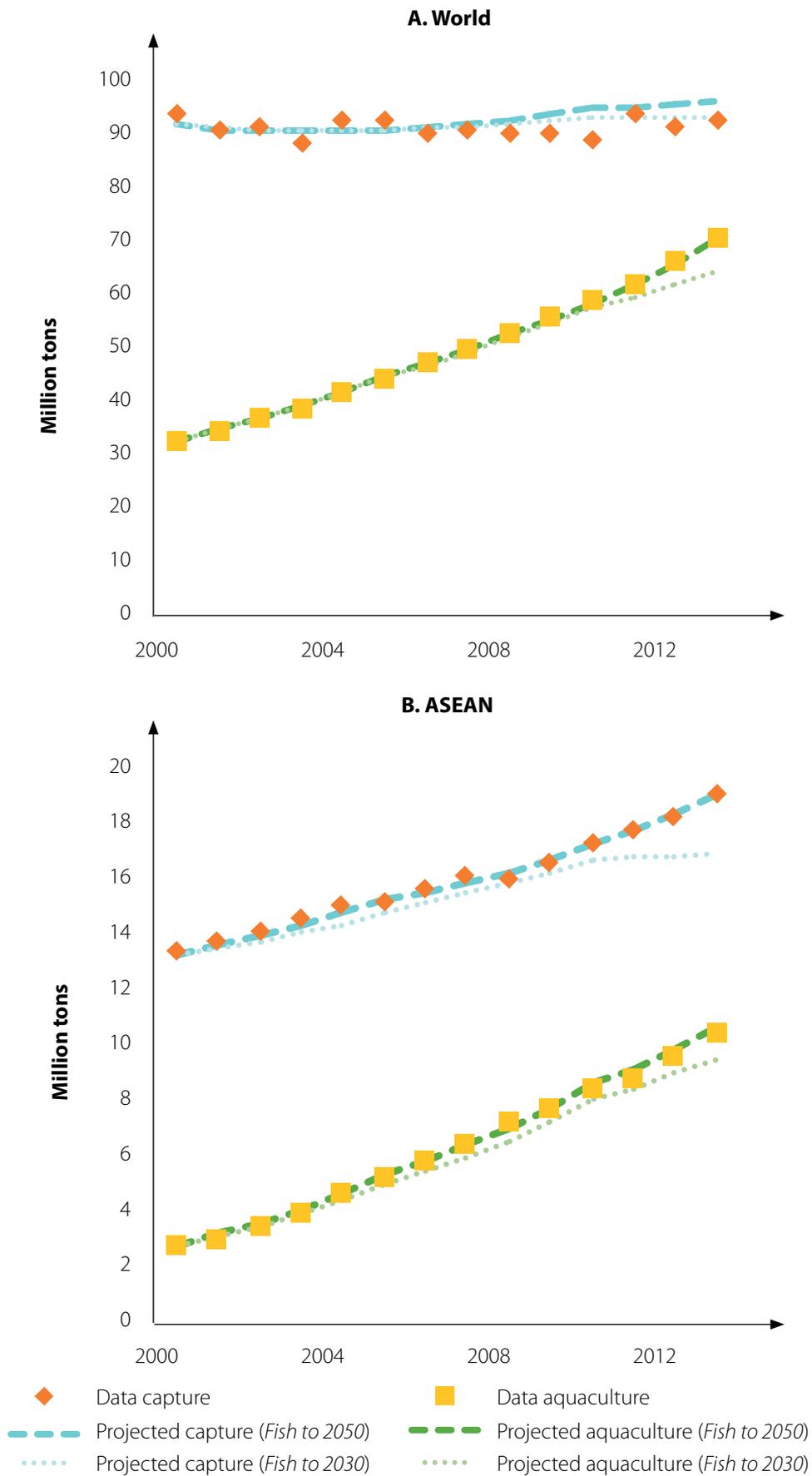
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Appendix A. Improvement of model calibration for historical trends



Appendix B. Stakeholder consultation workshop

To address future challenges, as well as improve priority setting and decision-making, there are increasing interests in food commodity foresight modeling and projections from policy-oriented researchers and national policymakers. Understanding the dynamics of fish production, consumption, trade, prices and their implications on food and nutrition security are critical to support policy and decision-making for ensuring sustained fish production growth while minimizing unexpected socioeconomic and environmental impacts. Nevertheless, fish commodities are commonly excluded in agriculture projection models. The IMPACT model is among a few taking into account fish projection at the disaggregated level. The *Fish to 2030* report in 2013 was the effort of a collaboration between the World Bank, IFPRI, the Fisheries and Aquaculture Department of the FAO and the University of Arkansas at Pine Bluff. This report built on the foundation of the *Fish to 2020* report conducted by IFPRI and WorldFish in 2003. These comprehensive global overview reports highlighted challenges, opportunities and roles that fisheries and aquaculture will play to meet the increasing global fish demand in the future.

As a research activity of the Global Futures and Strategic Foresight project, the IMPACT fish model was delivered to the WorldFish foresight modeling team in 2015. This is an interim step for the development of a full fish module linking to the updated version of IMPACT version 3. An updating effort was completed from the current dataset and parameters of the IMPACT fish model. The update focused on the ASEAN region and the top 10 aquaculture and capture fisheries producer countries. A stakeholder consultation workshop at WorldFish in June 2016 focused on improving the model calibration from the previous *Fish to 2030* report, with respect to industry-specific biophysical and socioeconomic factors, such as environmental and ecosystem carrying capacity and socioeconomic targets defined by national governments, among other dimensions in the ASEAN region.

The specific objectives of the stakeholder consultation workshop were to

- validate business-as-usual results of the region's fish supply and demand to 2050;
- explore maximum potentials/carrying capacity for fisheries and aquaculture among ASEAN countries;
- identify government targets/plans for fisheries and aquaculture in the ASEAN region;
- explore plausible futures of fisheries and aquaculture in the region by suggesting alternative scenarios.

The consultation brought together 20 specialists from 10 different countries (Australia, Bangladesh, Cambodia, Indonesia, Malaysia, Myanmar*, Philippines, Thailand, United States and Vietnam) from academia, government and NGOs representing a diverse range of expertise covering fisheries, aquaculture, trade and economics. The participants brought diverse experiences to explore the maximum carrying capacity and national government targets, as well as to the scenario setting and future visioning process.

*Myanmar's participant was absent during the workshop but attended the scenario meeting to provide input on 4–5 July 2016 in WorldFish, Penang.

List of workshop participants

No	Name	Affiliation	Organization country	Organization name
1	Benoy Kumar Barman	Senior Scientist	Bangladesh	WorldFish Bangladesh office
2	Olivier Joffre	Visiting Scientist	Cambodia	WorldFish Mekong Office
3	So Nam	Fisheries Team Leader	Cambodia	Mekong River Commission Secretariat (MRCS)
4	Dedi Adhuri	Guest Lecturer	Indonesia	University of Diponegoro
5	Sonny Koeshendrajana	Professor	Indonesia	Ministry of Marine Affairs and Fisheries (MMAF)
6	Zulkafli bin Abd. Rashid	Deputy Director General of Fisheries	Malaysia	Department of Fisheries, Malaysia
7	Haji Mazuki bin Hashim	Director of Aquaculture Development Section	Malaysia	Department of Fisheries, Malaysia
8	Zaki bin Haji Mokri	Head of Fisheries Data Collection Planning and Development Division	Malaysia	Department of Fisheries, Malaysia
9	Sallehudin Bin Jamon	Research Officer	Malaysia	Fisheries Research Institute Kampung Aceh
10	Khin Maung Soe	Consultant	Myanmar	WorldFish Myanmar office
11	Len Garces	Fisheries Management Specialist	Philippines	USAID Oceans: The Oceans and Fisheries Partnership
12	Paul Ramirez	Research Fellow	Philippines	WorldFish Philippines office
13	U-Primo E. Rodriguez	Professor	Philippines	University of The Philippines Los Baños
14	Ayut Nissapa	Associate Professor	Thailand	Prince of Songkla University Hat Yai
15	Pongpat Boonchuwong	Advisor	Thailand	Department of Fisheries, Thailand
16	Cao Le Quyen	Deputy Director	Vietnam	Vietnam Institute of Fisheries Economics and Planning (VIFEP)
17	Nguyen Thanh Viet	Associate Dean Faculty of Development Economics	Vietnam	Vietnam National University
18	Chu Hoang Long	Senior Lecturer	Australia	Australian National University
19	Chen Oai Li	PhD graduate	United States	University of Arkansas at Pine Bluff
20	Shahnila Islam	Research Analyst	United States	International Food Policy Research Institute (IFPRI)

Workshop process

WorldFish welcomed the participants in the opening remarks. The project leader facilitated the workshop and invited all participants to briefly introduce themselves. An overview of the research project, workshop agenda, objectives and expected output was given. The two-day workshop program was divided into five sessions: (1) overview of the IMPACT model, (2) present status and future prospects of country fisheries and aquaculture, (3) group discussion on country fisheries and aquaculture future prospects and maximum output/carrying capacity, (4) ASEAN alternative fisheries and aquaculture scenarios, and (5) fish foresight modeling alternatives and follow-up. During the first session, the IMPACT multimarket model and the IMPACT fish model were presented by IFPRI and WorldFish, respectively. This was followed by WorldFish's presentation on the updated parameters on the business-as-usual results of fish supply and demand in the ASEAN region to 2050 using the IMPACT fish model. In session two, the country teams presented the state of capture fisheries and aquaculture in their countries. Then in session three, using several specific questions, participants commented on the business-as-usual results/trajectories by exploring maximum carrying capacity and government targets for fisheries and aquaculture in their countries. This input allowed for a participatory approach to calibrate the future projection of the IMPACT fish model by the WorldFish foresight modeling team.

During the second day, in session four on scenario development, WorldFish narrowed down a major topic of interest that the participants could focus on for the region—climate change impact on both capture fisheries and aquaculture. The participants worked in three groups to develop narratives to come up with plausible scenarios for the future of fish. These were later quantified for the model. In addition to the IMPACT fish model, in

session five, other foresight models were presented: Firstly, the capture fisheries model to explore the maximum sustainable yield (MSY), then the AsiaFish model as an alternative country-level model and, lastly, the USFish model of demand side behaviors that could be adapted for use in other countries.

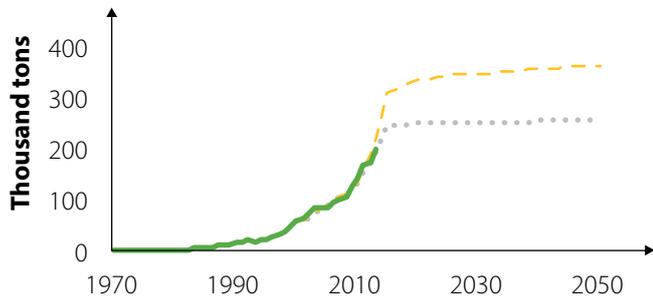
Workshop agenda

Tuesday June 7, 2016 (Day 1)	
8:30	Registration of participants
8:45	Opening remarks and welcome by WorldFish
Session 1 Overview of IMPACT model	
9:00	IMPACT model introduction
9:20	IMPACT fish model introduction (<i>Fish to 2030</i>)
10:00–10:20	Coffee break
10:20	IMPACT fish model update and preliminary baseline projection in ASEAN (<i>Fish to 2050</i>)
Session 2 Country fisheries and aquaculture present status and future prospects	
11:00	Country presentations – Bangladesh, Cambodia, Indonesia
12:00–1:10	Lunch
1:10	Country presentations – Malaysia, Philippines, Thailand, Vietnam
2:30–3:00	Coffee break
Session 3 Group discussion on country fisheries and aquaculture future prospects & maximum output/ carrying capacity	
3:00	Country group discussions
4:00	Country group presentations
4:30	Workshop adjourned for the day

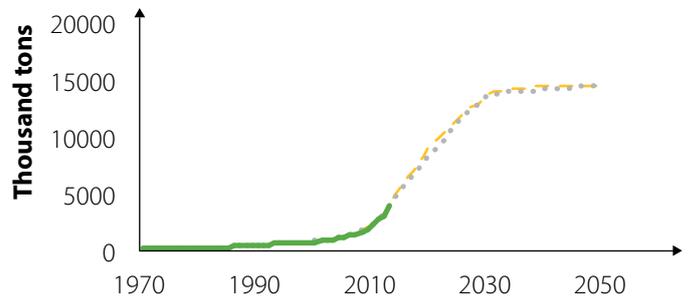
Wednesday June 8, 2016 (Day 2)	
Session 4 ASEAN alternative fisheries and aquaculture scenarios	
8:30	Scenarios development introduction
9:00	General discussion on scenarios development for ASEAN
10:00–10:20	Coffee break
10:20	Group discussions on selected scenario
11:20	Group presentations on selected scenario
12:00–1:10	Lunch
Session 5 Fish foresight modeling alternatives and follow-up	
1:10	Overview of fish foresight modeling approaches
1:30	Alternative fisheries modeling presentation (capture fisheries model, AsiaFish model, USFish model)
2:30–3:00	Coffee break
3:00	General discussion on fish foresight modeling ideas (group 1) Review of country consumption and trade projection results (group 2)
4:00	Concluding remarks and feedback
4:15	Adjournment

Appendix C. Calibration of the projected aquaculture production in the ASEAN region

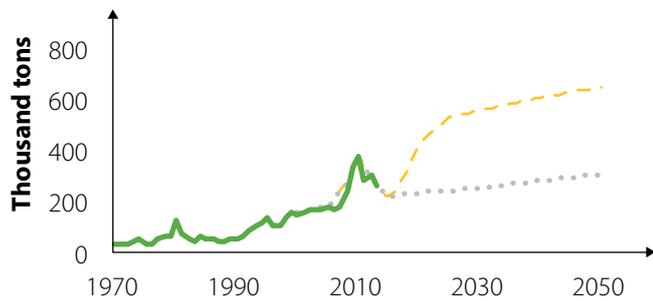
A. Cambodia and Laos



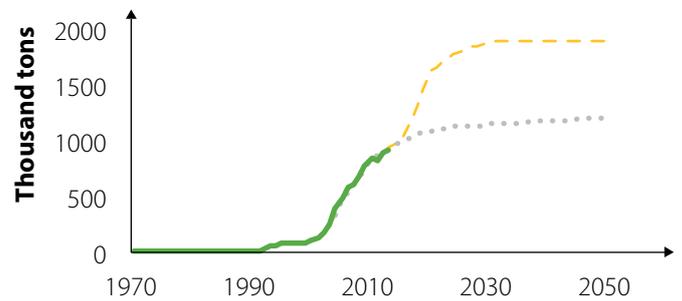
B. Indonesia



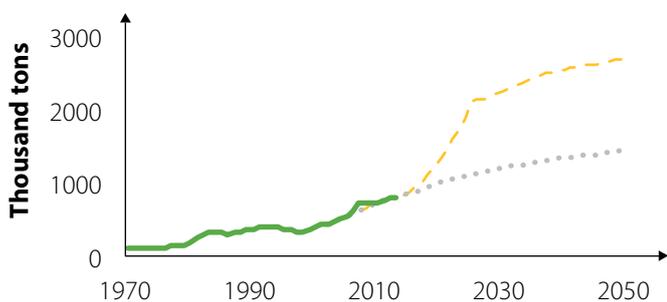
C. Malaysia



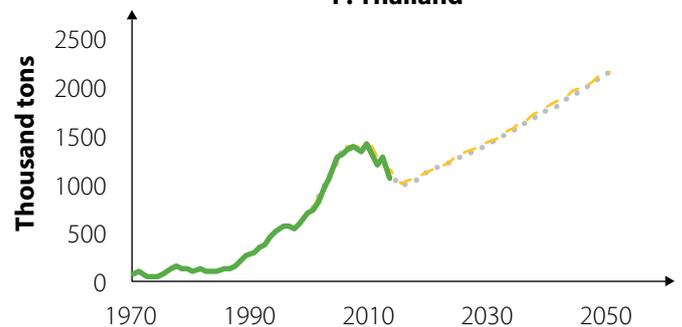
D. Myanmar



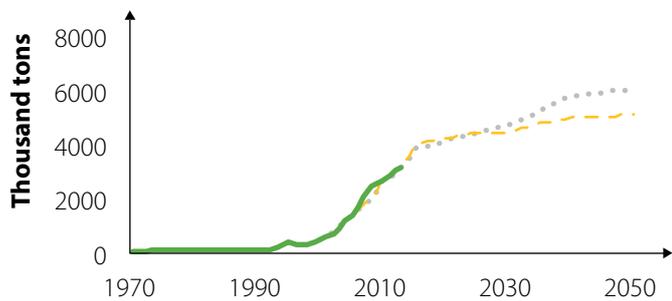
E. Philippines



F. Thailand

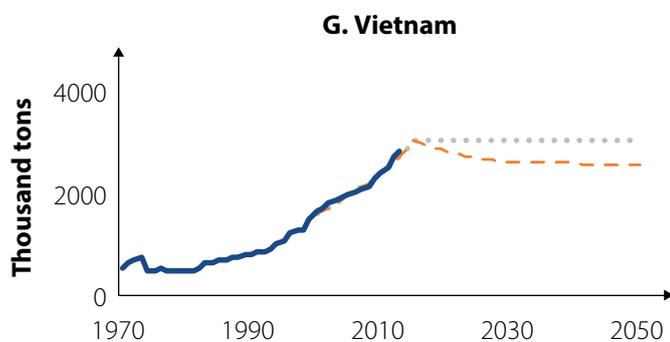
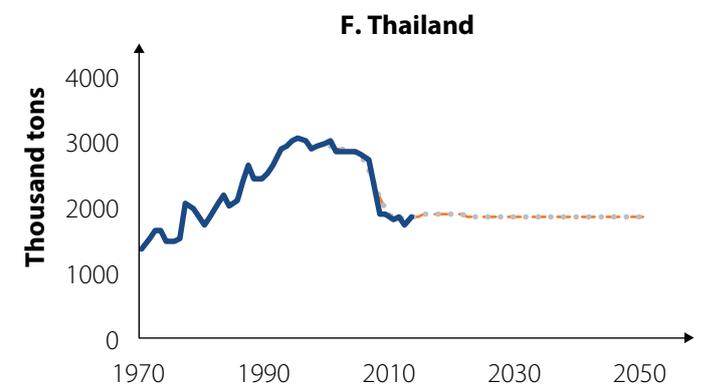
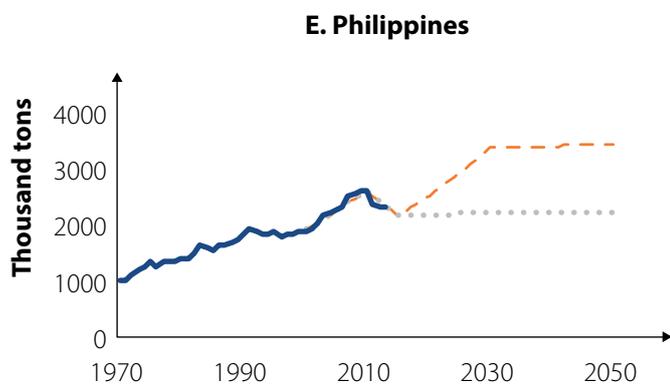
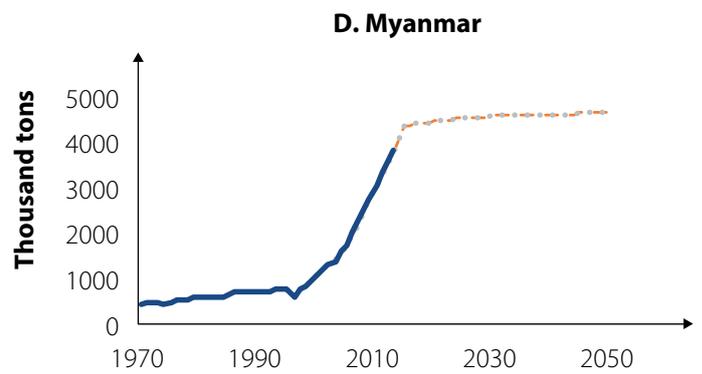
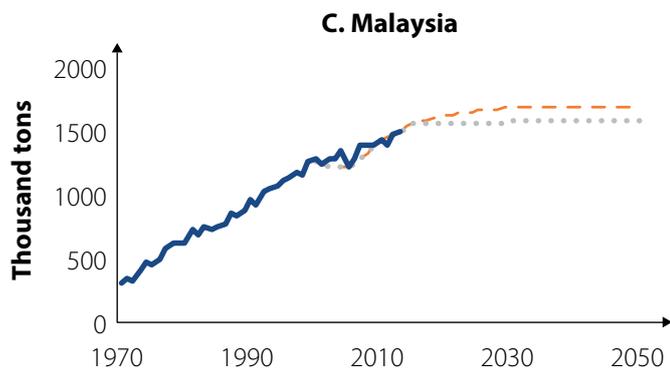
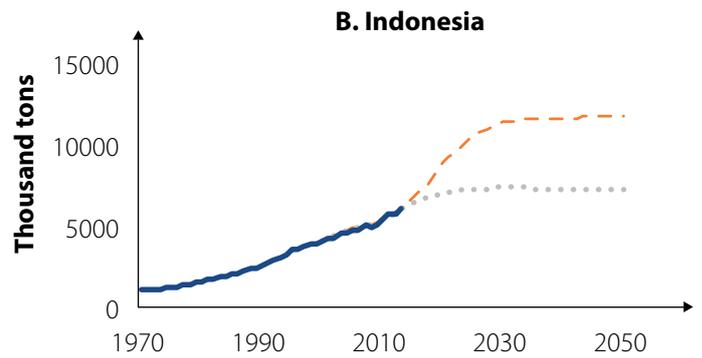
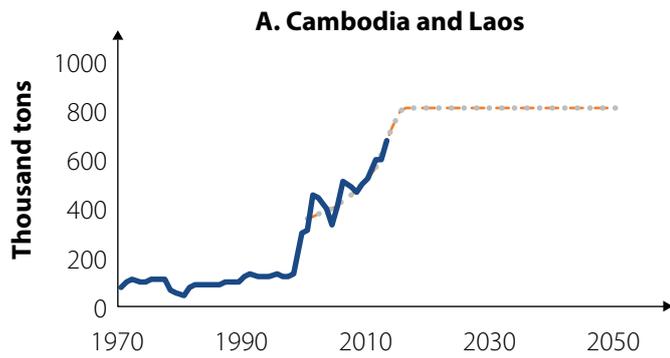


G. Vietnam



..... Original projection - - - - Revised projection — Historical data

Appendix D. Calibration of the projected capture fisheries production in the ASEAN region



..... Original projection - - - - Revised projection — Historical data



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