Asia-Pacific
Economic Cooperation

Advancing Free Trade
for Asia-Pacific Prosperity

Results of the Survey for the status of Aquaculture in APEC Economies

APEC Sub-Committee on Standards and Conformance

May 2023

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Aquaculture Status in APEC Economies, primary aquatics resources

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Acknowledgments

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**The information presented in this document refers to that is publicly available and other relevant information acquired by the creators during a survey requested to the participants of the project workshop.*

List of acronyms

APEC: Asian-Pacific Economic Cooperation
AMO: Amoxicillin
AMR: Antimicrobial Resistance
AMU: Antimicrobial Use
BMP: Best Management Practices
CAD: Canadian Dollar
CLO: chloramphenicol
CoC: Code of Conduct
CTC: Chlortetracycline
DOX: Doxycycline
ENR: enrofloxacin
EMS: Early Mortality Syndrome
ERY: erythromycin
FAO: Food and Agriculture Organization of The United Nations
FLO: Florfenicol
FLU: Flumequine
FSCF: Food Safety Cooperation Forum
GAP: Good Aquaculture Practices
GVP: Gross Value Production
HAB: Harmful algal blooms
HHNV: Hypodermal and Hematopoietic Necrosis Virus
IMTA: Integrated Multi-Trophic Aquaculture
MAR: Multi-Antibiotic Resistance
NF: Nitrofurans
OECD: Organization for Economies Co-Operation and Development
OFWG: Oceans and Fisheries Working Group
OMT: Ormetoprim
OTC: Oxytetracycline
OXA: Oxalinic Acid
QUI: Quinolones
SCSC: Sub-Committee for Standards and Conformance
SLD: Sulfadiazine
SLX: Sulfadimethoxine
SUL: Sulfonamides
TC: Tetracycline
TIA: Tiamulina
TIM: Timicosina
TiLV: Tilapia Lake Virus
TRI: Trimethoprim
UN: The United Nations
WOAH: World Organization for Animal Health
WFD: White feces disease
WSSV: White Spot Syndrome Virus

State of the art

The Asia-Pacific Economic Cooperation (APEC) was created in Canberra, Australia, in 1989 with twelve founding members, currently, there are twenty-one memberships from North-Central America, South America, East-Asia, South-Asia, Eastern Europe, and Oceania. The main objective is to support sustainable growth and prosperity for the economies that are part of this cooperation group.

The APEC Food Safety Cooperation Forum (FSCF) under the Sub-Committee for Standards and Conformance (SCSC) agreed toward harmonizing food with international standards, working collectively to strengthen capacity and information contribution, and where part of the work program contemplate initiatives on Antimicrobial Resistant (AMR). Under this context, the project "Strengthen and Expand Knowledge in Sustainable Aquaculture Production Practices to Reduce the Environmental Impact and Improve Food Safety of the Food Products (SCSC 02 2020A)", is seeking to enable members' economies to obtain knowledge and technical know-how on the best aquaculture practices under a one health approach. Leading to the responsible use of antimicrobials, minimizing the risk of leaving residues on the environment that lead to contamination and generating AMR in the water sources, and directly impacting food safety of products.

Aquaculture is one of the worldwide economic activities where AMR is a big concern because can cause detrimental effects on animals, the environment, and human health. According to the recent SOFIA Report, Food, and Agriculture Organization of The United Nations, FAO (FAO, 2022a), the fisheries and aquaculture sector reached an unprecedented production of 214 million tonnes (~United State Dollar (USD) $ 424 billion) which comes mainly from aquaculture. The total aquaculture sector was estimated at 87.5 million tonnes of Live Weight (TLW), where 54.4 million tonnes are produced in inland waters, while 33.1 million tonnes are produced in marine waters.

Aquatic food not only plays a key role in nutrition and food security; it is calculated that 20.2 k per capita was consumed in 2020; it also provides employs for an estimated 58.8 million, 35% belonging to the aquaculture sector, and about 21% is represented by women force (28% of women in aquaculture). Aquaculture and Fisheries are the fastest growing food-producer worldwide, where aquaculture's contribution to direct human consumption is more significant than the wild fisheries, mainly caused by overfishing consumption is more and fish stock deterioration (FAO, 2018). It is expected that the contribution of aquaculture will further increase to reach 202 million tonnes in 2030 (FAO, 2022a).

The aquaculture sector is the food production area in the world with the lowest carbon footprint (FAO, 2020). The sector has turned into the best way to provide food to the growing human population, beating for sustainable aquaculture production it will be possible to achieve the 2nd goal, Zero Hunger by 2030, which is part of the 17 goals proposed by the United Nations (UN, 2022).

Aquaculture in APEC members (Table 1) has brought a series of benefits as the economies work together to improve knowledge, infrastructure, investments, science, and business among other gains. The network component has been a relevant factor for improvements in Asian-Pacific regions, although challenges remain.

Table 1. Aquaculture production (Tonnes of Live Weight - TLW) by APEC economy. Reported data corresponded to production in 2020. *Selected species on this report; **Total species in culture reported by economy. Source: FAO (2022c)

No	Economy	Main species in culture	Production (TLW) selected species*	Total production (TLW) **
1	Australia	Oyster, Prawns, and Salmon	74,385.8	106,088.4
2	Brunei Darussalam	Catfish, Shrimp-Prawn, and Tilapia	3,069.9	3,500.0
3	Canada	Salmon, Mussels, and Oysters	138,940.0	171,007.0
4	Chile	Mussels, Salmon, Seaweeds	1,079,595.0	1,505,486.0
5	Hong Kong, China	Bivalves, Carp, Prawns, Shrimps, Tilapia, and other species	1,403.3	3,834.7
6	Indonesia	Carp, Catfish, Prawns, Shrimps, and Tilapia	4,046,152.0	14,845,014.0
7	Japan	Bivalves, Prawns, Seaweeds, and other species	30,987.0	996,297.3
8	Malaysia	Carp, Catfish, Prawns, and Tilapia,	140,969.1	400,017.0
9	Mexico	Bivalves, Carp, Prawns, Shrimps, Tilapia, and other species	263,009.8	278,693.8
10	New Zealand	Mussels, Oysters, and Salmon	15,511.0	118,582.0
11	Papua New Guinea	Carps, Mussels, Salmon, Shrimp, Tilapia	1,800.0	6,102.0
12	People´s Republic of China	Carp, Catfish, Prawns, Seaweeds, and Tilapia	28,706,821.0	70,483,538.5
13	Peru	Salmon, Scallops, Shrimp, and Tilapia	92,548.2	143,829.7
14	Republic of Korea	Bivalves, Halibut, Mollusc, Prawns, Seaweeds, and other species	27,112.0	3,008,203.0
15	Russia	Carp, Mussel, Salmon, Scallops, and Seaweed	233,629.0	291,194.0
16	Singapore	Carps, Catfish, Shrimp-Prawns, Tilapia, and other finfish	309.7	4,828.9
17	Chinese Taipei	Tilapia, Milkfish, Clam, Groupers, Oyster, Seaperch, and Threadfin	204,621.3	278,503.2
18	Thailand	Carps, Catfish, Shrimp, and Tilapia	764,379.0	962,466.9
19	The Philippines	Carps, Catfish, Groupers, Mussel, Prawn, and Tilapia	344,859.0	2,322,831.4
20	The United State	Catfish, Salmon, and Tilapia	152,232.8	488,534.6
21	Viet Nam	Bivalves, Carp, Catfish, Shrimps, Tilapia, and other species	3,402,700.0	4,614,692.0
		Total	**39,603,754.2**	**100,993,244.4**

From the top ten aquaculture producer economies, six out of twenty-one APEC member economies are recognized as the top ten aquaculture producers: People's Republic of China (1), Indonesia (2), Viet Nam (4), Republic of Korea (4), The Philippines (5), and Chile (9) (Figure 1). P.R. China has been for years the primary producer with 35% of the total aquaculture production worldwide and 37% of aquatic animal production in 2020. The contribution of the Asia region is 90% of the total worldwide production (FAO, 2022a).

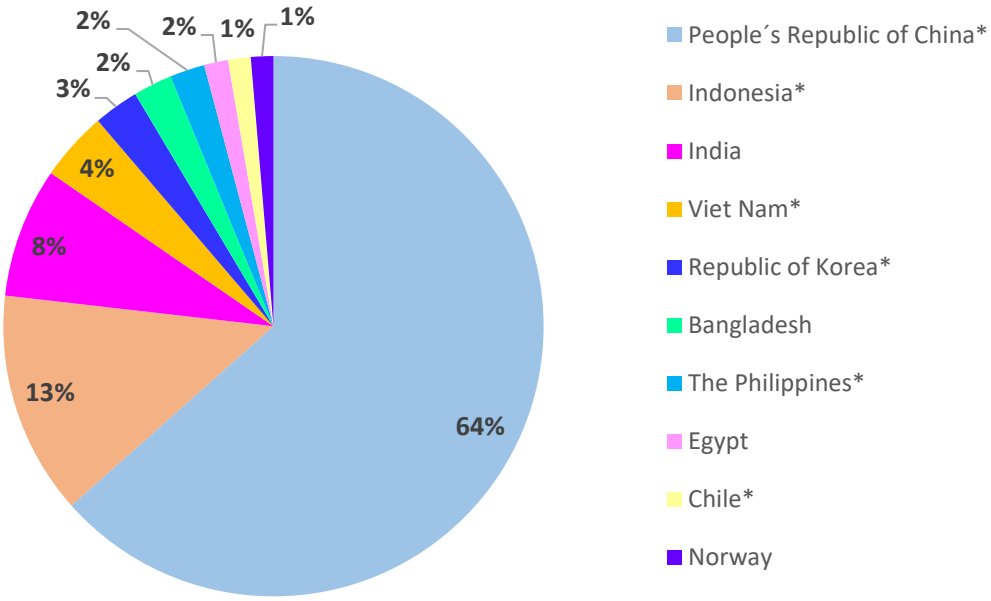


Figure 1. Total aquaculture production in top-ten worldwide economies 2020. Production in Tonnes of Live Weight (TLW). *Indicates APEC economies Source: FAO (2022c).

For this report, we selected aquaculture species that are the most important aquatic-farmed species in terms of production, and value, contribute with rural livelihoods, world trade, and are relevant to APEC economies. The selected species Carps, Catfish[1], Salmon[2], Shrimp-Prawns, and Tilapia (Table 1) are the most valuable aquaculture species that significantly contribute with a protein source to the human population. Based on the information available on the FAO (FAO, 2022c), the last eight years (2012 to 2020) of aquaculture production for the species detailed before were selected. By using the criteria “name of each economy”,“Detailed production source”, and “Aquaculture production”, the data[3] was cleaned by the APEC economies and the species of interest. Consequently, the statistics presented by the economy represented the aquaculture production of the relevant species listed earlier organized by region North-Central America, South America, South-East Asia, East-Asia, Eastern Europe, and Oceania (Fig. 2).

[1] *Catfish refers to Catfish and Pangasius*

[2] *Salmon refers to the order salmoniformes: Salmon and Trucha*

[3] *Does not include "Miscellaneous" classification*

APEC

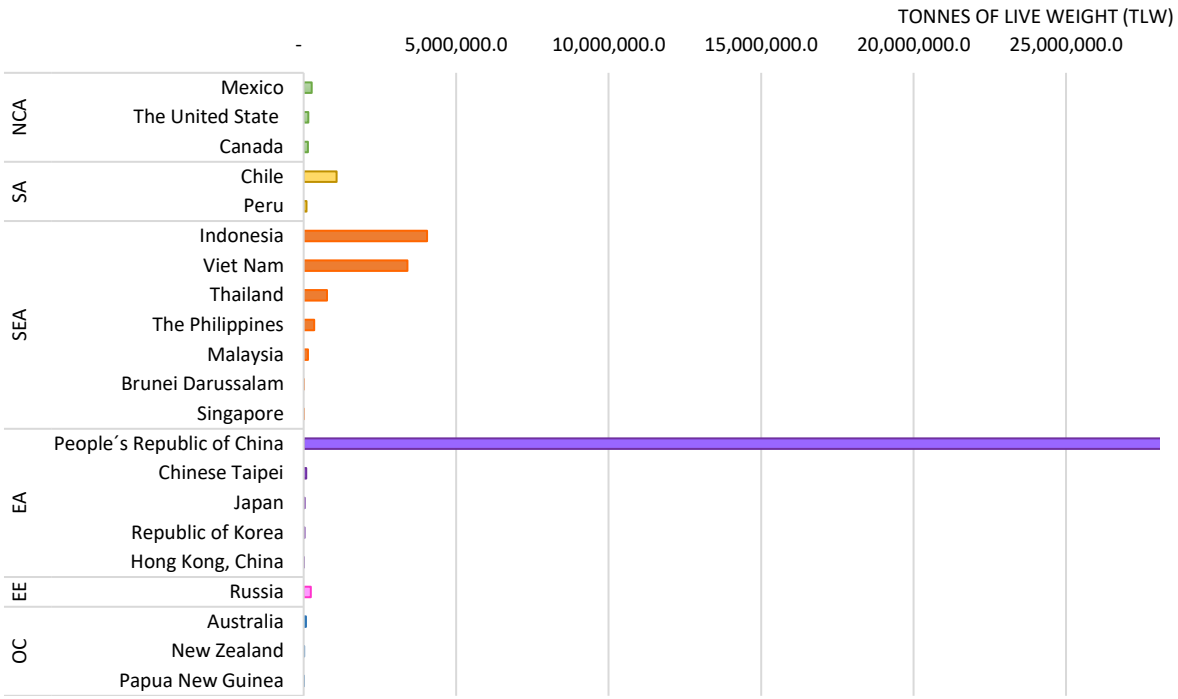


Figure 2. Regional aquaculture production in APEC economies (selected species in this report), 2020 production in Tonnes of Live Weight (TLW). NCA: North-Central America; SA: South America; SEA: South-East Asia; EA; East-Asia; EE: Eastern Europe; OC: Oceania. Source: FAO (2022c).

NORTH-CENTRAL AMERICAN ECONOMIES

In North-Central American economies, the dominant farming species are Shrimp-prawns, Salmon, Catfish, Tilapia, and a little Carps production (Fig. 3). The production until 2020 follows the global trends, which means an increment in aquaculture production. Mexico is a top-ten shrimp producer, while Atlantic and Pacific salmon production is dominated by Canada.

Interestingly, this region holds two of the major Tilapia imported globally, The United State of America (USA) and Mexico, the USA is also the major Shrimp imported (Miao & Wang, 2020).

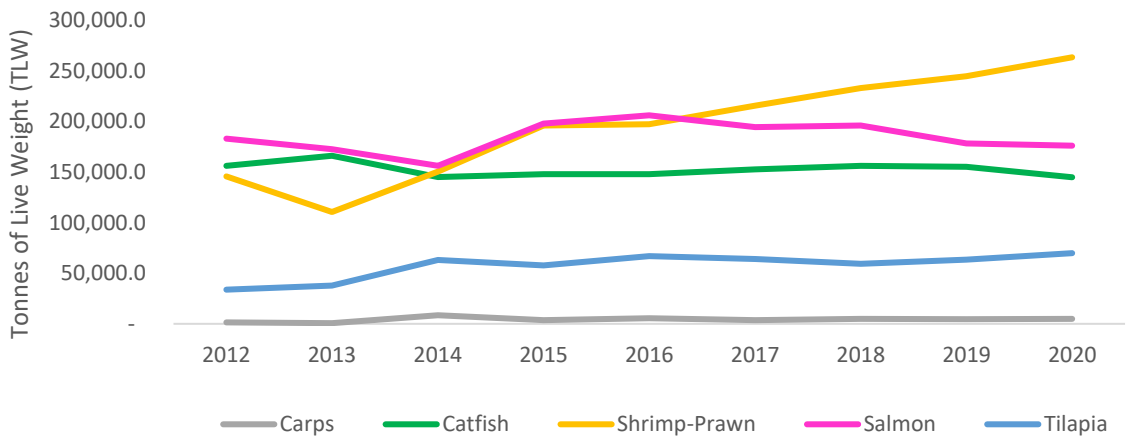


Figure 3. North-Central America aquaculture production (Tonnes of Live Weight - TLW) for relevant species from 2012 to 2020. Source: FAO (2022c)

Canada

Fish farming in Canada is jointly managed among federal, provincial and territorial governments. How it's managed varies across provinces and territories. Aquaculture activities occur in all provinces, where a dozen types of fish are produced as well as shellfish aiming for a healthy and sustainable industry. The aquaculture industry employs thousands of Canadians and by 2020 reached 3,785 direct jobs generating Canadian Dollar (CAD) $140 million in labour income. The social impact of the sector involves many Indigenous communities across Canada as well as rural and coastal communities. In 2021, the sector generated CAD $1.34 billion, with a production volume of 191,249 tonnes (Statistics Canada, 2022).

Canada is the fourth-largest producer of farmed salmon in the world and mussel is the top shellfish aquaculture export. Atlantic and chinook salmon, trout, Arctic char, mussel, oyster and clam are well established aquaculture industries, while the farming of several other species are at various stages of development. Other species include marine plants, sea cucumber, crayfish and sea urchins, produced in small amounts.

Atlantic salmon is by far the most important aquaculture product in Canada. In 2021, salmon accounted for 74% of production value followed by other finfish with 17% of the total value. Shellfish accounted for 9% of production value. Production of Atlantic salmon in Canada was 120,186 tonnes in 2021 and the production on tonnes of live weight from 2012 to 2020 is shown in Fig. 4. In terms of aquaculture value, salmon production in 2021 reached CAD $999,583,000 which represents 78.8% of the total aquaculture value CAD $1,344,745,000. Canada is the fourth-largest producer of farmed salmon in the world.

The industry follows strict regulation, biosecurity, and certification of products and protocols to minimize pathogen introduction, contaminants and toxins. Health Canada provides optimal care for animals, prevents diseases, uses vaccines, treats sick animals efficiently, prescribes treatment by licensed veterinary, and minimizes the use of drugs. Part of the regulations ensures the use of chemicals is restricted to ensure no harmful effects on the environment (Canadian Aquaculture Industry Alliance, 2020). Regarding antibiotic regulations, Canada has listed four drugs; florfenicol (FLO), trimethoprim (TRI)/sulfadiazine (SLD), ormetoprim (OR)/sulfadimethoxine (SLX) and oxytetracycline (OXT), allowed for aquaculture use, but erythromycin (ERY) could also be used in emergency cases (Henriksson et al., 2018; Health Canada, 2022). While other substances such as Chloramphenicol (CLO), Nitrofurans (NF), and Flumequine (FLU) are banned for all species on farms (Karunasagar, 2020).

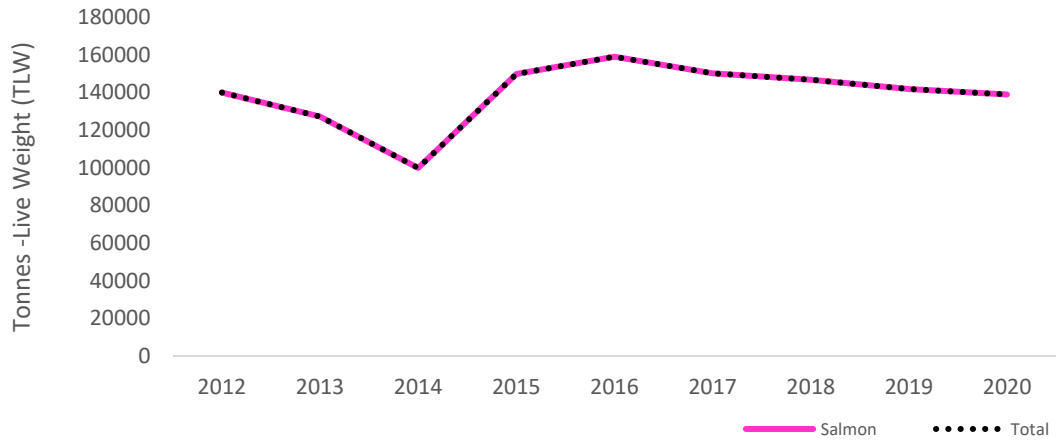


Figure 4. Canada aquaculture production (Tonnes of Live Weight - TLW) for a relevant species, Salmon, from 2012 to 2020. Source: FAO (2022c)

Mexico

The Aquaculture and Fisheries sector is a relevant sector for this economy, for the aquaculture sector the production for 2019 was estimated at 251,000 tonnes. This sector generates employment for 56,250 people, where 8% is represented by women's force and 92% to men's force (Vázquez-Vera & Chávez-Carreño, 2022)

Mexico is in the top-ten shrimp producer economies in the world, the main species is *Penaeus vannamei,* producing 200,000 tonnes/year (Fig. 5). The second relevant species in culture is Tilapia (*Oreochromis* sp. and *Tilapia* sp.) with 60,000 tonnes/year (Fig. 5). The aquaculture production is based in freshwaters and marine waters, and the consumption is mainly by the domestic market. Counts with 9,320 aquaculture installations that occupied 115,910 hectares dominated by the semi-intensive cultured system (Vázquez-Vera & Chávez-Carreño, 2022)

For many areas of Mexico, marine resources is the main protein source consuming an estimated 14.2 kg per capita in 2017. However, from the aquaculture production, part of the shrimp production is destinated to the United State market, meanwhile, Tilapia is destinated to P.R. China market. Other resources in culture are Rainbow Trout (*O. mykiss* – 8,000 tonnes/year), River Trout (*Salvelinus fontinalis*), Carp (*Cyprinus carpus* – 4,000 tonnes/year), and mollusks among other species.

Mexico manages certifications, such as, the Best Aquaculture Practices and Aquaculture Stewardship Council, which opened doors for worldwide markets. Additionally, this economy has invested in scientific work to improve knowledge, strength capacities, and biotechnology. This economy adopted in 2018 the *"National Action Strategy against AMR*", the strategy meets the One Health approach to reduce AMR and improve scientific knowledge in human and animal health among other objectives (DOF, 2018)

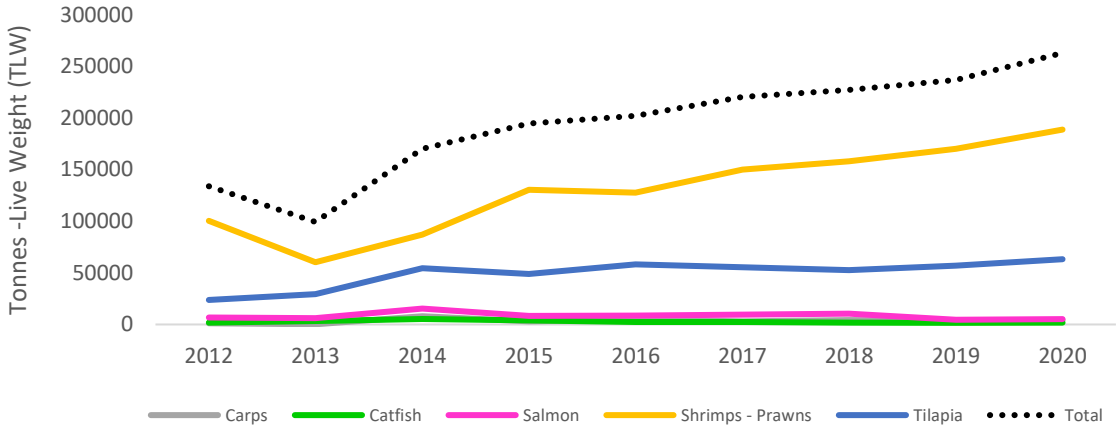


Figure 5. Mexico aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, Salmon, Shrimps-Prawns and Tilapia, from 2012 to 2020. Source: FAO (2022c)

The United State of America

The USA is a minor aquaculture producer. The aquaculture industry is primarily produced in freshwaters that generated USD $694 million (257,187 metric tons), the main species in culture are catfish, *Ictalurus punctatus* (157,847 metric tons), crawfish (73,676 metric tons), and salmon, *O. mykiss* and *S. salar* (15,322 metric tons). While in marine waters produce USD $430 million, the main species is the Atlantic salmon (estimated 14,484 metric tons), other resources include shrimp such as Northern White Shrimp (*Penaeus setiferus)*, White leg Shrimp (*P. vannamei)*, Giant River Prawn (*Macrobrachium rosenbergii*), and mussels (FAO, 2020; National Marine Fisheries Service, 2022). Aquaculture production of the selected species in this report are presented in figure 6.

Most of the aquaculture production is consumed in the domestic market (6.6 kg per capita), while the other parts are going for exportation and industrial products such as meal and oil, bait, and animal feed. This economy based the seafood consumption in the products importation, 70-85% of the seafood coming from another foreign aquaculture and is the largest shrimp importer.

The USA manage good practices for fish production, antibiotics may be used under control and directed by a U.S. licensed Veterinarian. The veterinarian gives a diagnosis, treatment and provides a prescription. The drug for medication is approved by the Food and Drugs Administration agency (FDA) within the Department of Health and Human Service (NOAA, 2022), where only SLX /OMT, OTX and FLO are allowed for aquaculture use (Henriksson et al., 2018).

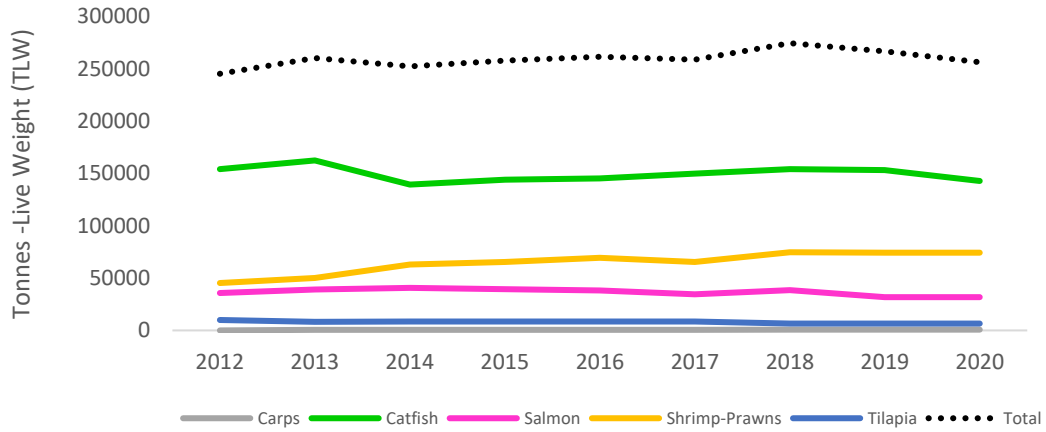


Figure 6. The United State of America' aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, Salmon, Shrimps-Prawns, and Tilapia, from 2012 to 2020. Source: FAO (2022c)

SOUTH AMERICAN ECONOMIES

This region holds one of the biggest salmon producers, Chile, which is the second worldwide Salmon producer after Norway, as such the main species farmed in this region is salmon led by this economy (Fig. 7). The main specie in culture is the Atlantic salmon, *Salmo salar*, although there are other salmon species and trout which are farming. Peru has little production of salmon, mainly trout, but it continues to be the main farmed species for this economy if the other farmed species, Catfish, Shrimp-Shrimp and Tilapia are considered.

In this region, there is no Carps farming for none of the economies part of the APEC. While for the selected species in this publication, Chile only holds Salmon farming.

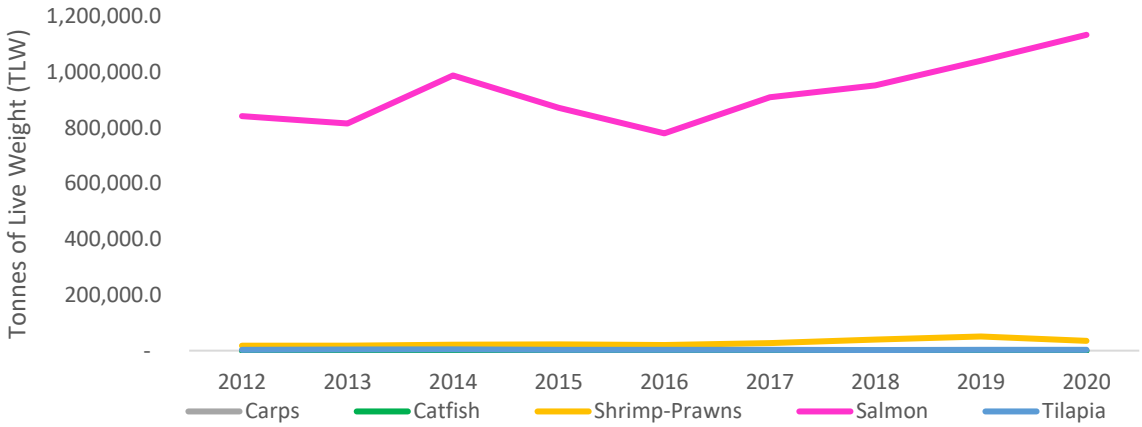


Figure 7. South America aquaculture production (Tonnes of Live Weight - TLW) for relevant species from 2012 to 2020. Source: FAO (2022c)

Chile

The aquaculture sector is the second economic activity of the APEC member, based mainly in salmon farming, Chile is the second salmon producer worldwide after Norway. In 2020, the salmon production reached 1,075,896 tonnes (SERNAPESCA, 2020) (Fig. 8). However, the aquaculture production is exported as the population consumed very low level of seafood.

The aquaculture subsector is concentrated in the south of the territory where the operation is based on freshwater, estuarine and marine water. Until 2008 where 3,600 authorized sites that represent about 33,000 hectares. The most important aquaculture species are Atlantic salmon (*S. salar*), Salmon Coho (*O. kisutch*), and Rainbow trout (*O. mykiss*). The second important culture resource is the mussel industry that are in areas close to salmon farms, the main mussel species in culture is *Mytilus chilensis* (www.subpesca.cl).

Chile counts with strong regulations which include the prohibition of the use of specific antibiotics (e.g., chloramphenicol and its derivatives) in aquaculture and require the registration and approval of new antibiotics drugs through the Agricultural and Livestock Authority (SAG) after environmental risk assessments are completed. A mandatory program tests salmon products for antibiotics residues before commercialization in domestic or external markets. The regulations are under the General Fish and Aquaculture Law that manage the preservation, harvesting and investigation in marine and coastal resources. Chile is one of the few economies where exists access to the antibiotics use data that is reported by the authority, as well as the authorized compounds.

The use of chemical drugs is administered by licensed veterinary that prescribe the drug and the dose, the medication is given as medicated feed pellets formulated by feed manufacturers, and where producers and feed manufacturers are obligated to register and separately report their antibiotics usage to authorities; and this information is aggregated and published in an annual report and submitted to the World Organization for Animal Health (WOAH). Veterinary drugs allowed are FLO, OTC, ERY, Timicosina (TIM) y Tiamulina (TIA), 97.5% is applied in marine water farms (SERNAPESCA, 2020). Regarding the use, antibiotics can not be used as growth promoters or for prevention of diseases. The prescription must be done by a Veterinarian and be supported by diagnosis.

In 2016 the Chilean Fisheries and Aquaculture Service (SERNAPESCA) began a program to certify marine salmon farms as antibiotics-free, to help reduce their environmental impacts, the Chilean Salmon Antibiotic Reduction Program (CSARP) is a broader collaboration initiative to improve practices and one where the salmon industry aims to reduce antibiotics use by 50% between 2017 and 2025 (https://www.csarp.cl/). Also, there exist other monitoring and surveillance programs for Harmful algal blooms (HABs) and for the Mussels industry.

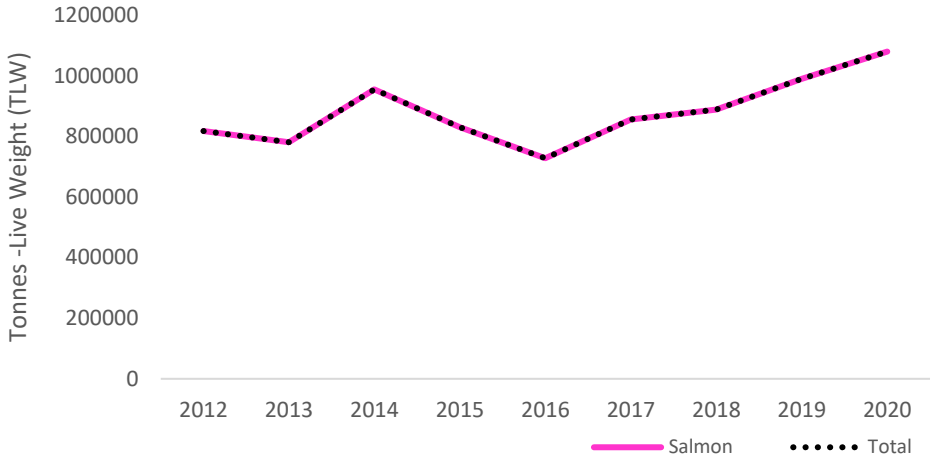


Figure 8. Chile aquaculture production (Tonnes of Live Weight - TLW) for a relevant species, Salmon, from 2012 to 2020. Source: FAO (2022c)

Peru

The aquaculture sector for this economy is governate by the Minister of Production and the sector is one of the main activities as it contributes to local development, generates employment, and contributes to nutritional food for the population (PRODUCE, 2020).

The aquaculture production is based on 30,613 hectares of fresh and marine waters, where the main resources are Rainbow Trout *O. mykiss* (37.7%), Scallops *Argopecten purpuratus* (33.1%), Prawn *P. vannamei* (24.5%), and Tilapia *Oreochromis niloticus* (2%), production by species is presented in figure 9. The main market is domestic as the total population consumes seafood of 17.28 kg per capita. Although there are still areas of the economy where seafood has low consumption, the economy administration created a program "Eat Fish" which is expected to arise the consume to 27.6 kg per capita. Part of the aquaculture products are exported; the main exported resources are Scallops and Prawns, and the main destination is The United States of America (36.9%) (PRODUCE, 2020).

The aquaculture production is regulated by Law Ley N.27460(2001) and the regulation D.S.N. 030-2001. The Technological Fisheries Institute (ITP by its acronym in Spanish), is the competent authority that regulates sanitary conditions, certifications, and quality of resources. While the antibiotic used in aquaculture is regulated by the Peru´s Sanitary Fisheries Organism (SANIPES, by its acronym in Spanish), this institution established the antibiotics limits in seafood, the allowed antibiotics are Amoxicillin (AMO), FLO, FLU, ERY, OTC, Oxolinic Acid (OXA) and Sulfonamidas (SULF), while banned antibiotics are CLO, NF, Nitroimidazoles (Huanambal, 2020; SANIPES 2022). This economy follows its own Antimicrobial Resistant Program which follows the one Health approach for the 2019 - 2021 determined period (Huanambal, 2020).

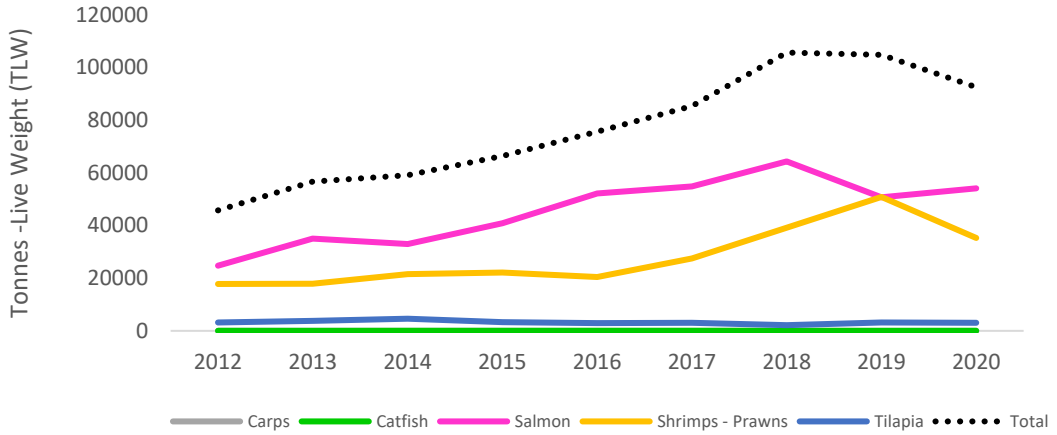


Figure 9. Peru aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, Salmon, Shrimps-Prawns and Tilapia, from 2012 to 2020. Source: FAO (2022c)

SOUTH-EAST ASIAN ECONOMIES

This region hosted fourth of the top-ten aquaculture producers worldwide: Indonesia, Thailand, Viet Nam and The Philippines. The aquatic production is led by the Catfish production followed by Shrimp-Prawn, Tilapia and carps, and a very little salmon production (Fig. 10). Viet Nam is one of the biggest Catfish producers for this region, followed by Indonesia and Malaysia. In this region, there is no salmon farming.

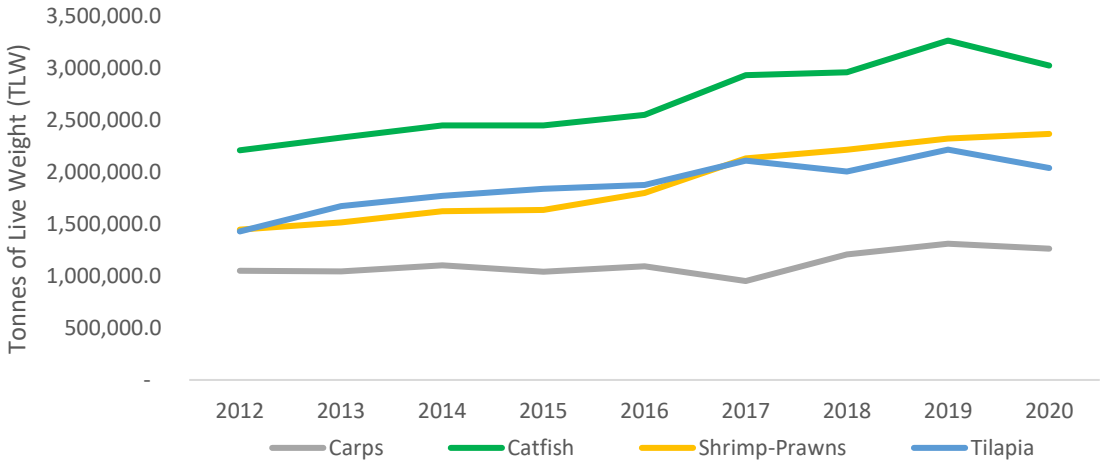


Figure 10. South-East Asia aquaculture production (Tonnes of Live Weight - TLW) for relevant species from 2012 to 2020. Source: FAO (2022c)

Brunei Darussalam

Aquaculture has been incorporated as one of the main goals for the economy with the aim of 1) increasing aquaculture industry productivity through genetic development and selective breeding programs, 2) developing of sites for the industry, 3) increasing aquaculture production and 4) a breeding plan for the prawn industry.

The Brunei Darussalam administration has stated to increase fisheries output to USD $404 million. To achieve the proposed goals the economy promoted exporting-driven aquaculture activities for investors (Estribillo & Hiramoto, 2021).

The main aquaculture products (Fig. 11) are shrimp such as the Blue shrimp (*Neocaridina* sp.), White leg shrimp (*P. vannamei*) and Giant River prawn (*M. rosembergii*), and fish such as Tilapia (*O. niloticus*), Catfish (undetermined species), among other (Pompano, Grouper and Snapper). The production is generated in ponds, marine waters, freshwater, and recirculating systems. In 1990 the economy created a program for investment and increasing aquaculture production that allowed to begin exportations to the USA in 2000. Having a small territory and limitation of water resources, aquaculture turns into an important sector for seafood production.

The sector has been increasing considerably since 2000 reaching USD $110.84 million in 2015, showing a decline in 2018 and 2019, and retaking good production in 2020 contributing with USD $139.05 million. Aquaculture production is mostly for domestic consumption as Brunei Darussalam is top ten in fish consumption per capita, and a small part of the production is exported to other Asian economies (e.g., China, Japan, and Korea) and Australia.

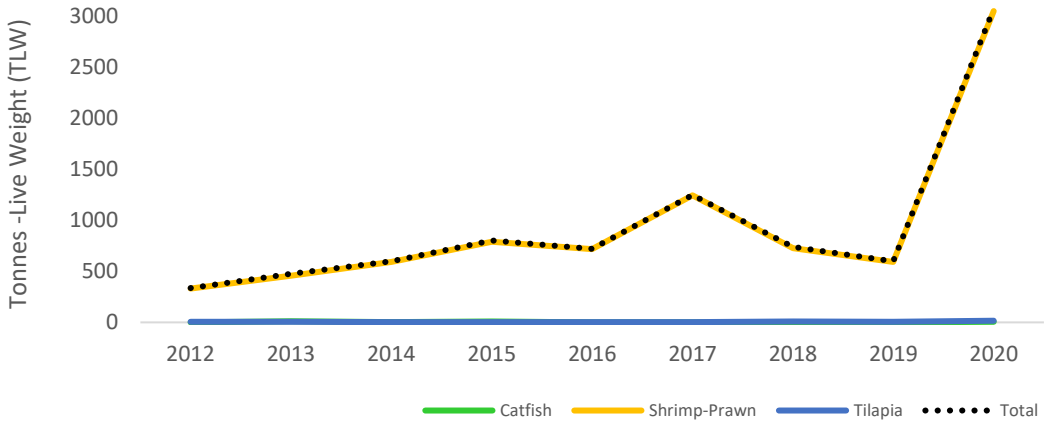


Figure 11. Brunei aquaculture production (Tonnes of Live Weight - TLW) for relevant species Catfish, Shrimps-Prawns and Tilapia, from 2012 to 2020. Source: FAO (2022c)

Indonesia

This economy is one of the top-ten aquaculture producers worldwide. The aquaculture sector is based on fresh, brackish, and marine waters, where 80% of the aquaculture industry is small-scale (Coyne et al., 2019). The White leg Shrimp (*P. vannamei*) is the principal exportation marine resource (Fig. 12). Other relevant species are Catfish (*Clarias* sp. and *Pangasius* sp.), carp (C*yprinus carpio)* and Tilapia (*O. niloticus*) (Fig. 12), while other marine resources include seaweeds, sea cucumber, and other finfish (FAO). Indonesia is the main fish producer in Southest Asian, fish is also the main seafood present in the domestic market (33.76 kg/ year per capita in 2014) as Shrimp is considered as an expensive product. The shrimp production, , about 38% , is exported to the USA, Japan and the European Union (Coyne et al., 2019).

The aquaculture governance is regulated by the Fish Law No.31/2004, they also manage training, education (i.e., University, Institutions, Research Centers), and invest in research. In fact, the economy has invested in programs to intensify the aquaculture sector responding to the high demand, like the creation of the Domestic (NBC) and Regional Breeding Centre (RBC) for reproduction of some species such as Tilapias, Shrimp, and seaweeds. The aquaculture sector exports most of the production placing Indonesia as the second major producer after China, where the main markets are Japan, Hong Kong China, Singapore, the European Union, Australia among others. (Halim & Juanri, 2016).

The shrimp industry faced health issues by disease outbreaks such as White feces disease (WFD) and the White Spot Syndrome Virus (WSSV) that can reduce in 30% the production. There are not treatment or methods to control the diseases and the farmers mainly bet on preventive measures such as water quality checks (i.e., pH, carbon content and dissolve oxygen levels). Today, no vaccines have been developed to treat these viral diseases, and the farmers try to prevent by using probiotics in feed for mitigation (Halim & Juanri, 2016).

Little is known about antibiotic use and its impact on the aquatic environment in this economy, previous studies did not find publicly available data regarding antibiotic use for this economy, (Lulijwa et al., 2020). In a recent study by Hidayati et al. (2021) was the first-time reported information on pharmaceutical drugs presence in shrimp aquaculture surrounded areas, where OTC was the most present antibiotic in all studied regions of Indonesia.

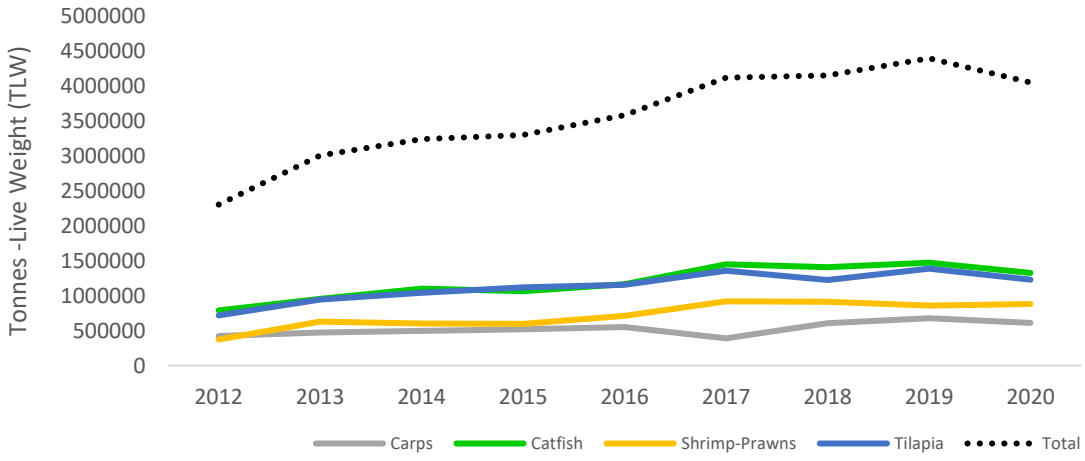


Figure 12. Indonesia aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, Shrimps-Prawns and Tilapia, from 2012 to 2020. Source: FAO (2022c)

Malaysia

The aquaculture production is based in fresh waters where the main cultured species are Tilapia (*Oreochromis* sp.), Catfish (*Pangasius* sp.), and Prawn (*M. rosenbergii*), also in marine waters where the main species are Black Tiger Shrimp (*Penaeus monodon*) and White Shrimp (*P. vannamei*) (Fig. 13), seabass, mussels and seaweeds. The aquaculture covers 20,000 hectares where ponds, pens, long-lines, tanks, and other types of systems for fresh and marine waters are based (Kuriawan et al., 2021).

The sector plays a relevant role for the economy supplying food for the domestic consumption, providing employment, career developments, investment opportunities, diminish the pressure on fisheries, and generate foreign exchange, among other benefits. The domestic markets are based on fresh and frozen products, and where the per capita consumption has increased. Exportation markets includes the following economies: Singapore, Hong Kong China and P.R. China.

The aquaculture production is managed by the Department of Fisheries (DFO). The farmers are grouped in associations Fishermen´s Association Act (1971) and registered with the Fisheries Development Authority of Malaysia (LKIM). The Ministry of Agriculture managed the Department of Veterinary Services that control and care about animal health. The food safety is regulated by the law Food Act (1983) and Food Regulations (1985) that deal with standards for fish products. The economy also manages programs for product certifications, accreditation programs, and best veterinary practices (Jumatli & Ismail, 2021).

The Malaysia Pharmaceutical Regulatory Agency (NPRA), under the Ministry of Health, regulates the use of antibiotics. For aquaculture use, oxytetracycline (OTC) and chlortetracycline (CTC) are allowed drugs, while other such as CHL, NITRO, enrofloxacin (ENR) and tetracycline (TC) has been banned. Although, Malaysia banned CLO and NF, the FDA has detected residuals of these products on Malaysia seafood (Thiang et al., 2021).

While the Fisheries Biosecurity Division of the Department of Fisheries of Malaysia managing the Aquaculture Residue Monitoring Program (ARMP) that compiles records of the drugs residuals (Karunasagar 2020) a study from Thiang et al , 2021, identified 23 antibiotics from six different types of drugs which were obtained from 29 aquaculture farms, in average each farm used 5 different types of antibiotics, the maximum amount of detected antibiotics was 9 in finfish farms and 11 in shrimp farms. However, there is a lack of oficial data available on antimicrobial use (Noordin et al., 2020).

This economy initiated the Antimicrobial Resistance Committee (NARC) in 2016, following the One Health approach, the main objectives of the program are public awareness and education; research and surveillance; prevention and control of infections and the appropriate use of antimicrobials (Noordin et al., 2020).

Some of the challenges that Malaysia faces are the disease outbreaks such as the Tilapia Lake Virus (TiLV) that caused significant mortality in Tilapia (~90%) and the Early Mortality Syndrome (EMS) that caused mortality in *P. monodon* and *P. vannamei.* (Fathi et al., 2018).

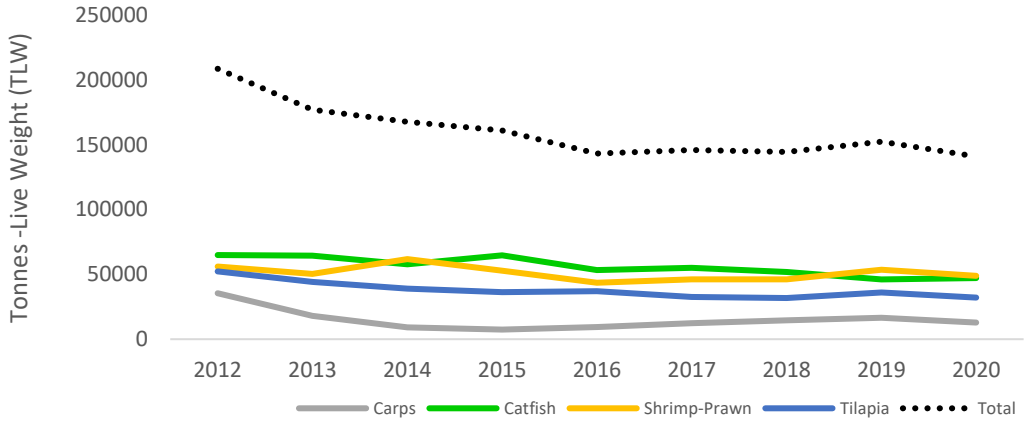


Figure 13. Malaysia aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, Shrimps-Prawns and Tilapia, from 2012 to 2020. Source: FAO (2022c)

Singapore

The aquaculture industry in Singapore is very small and incipient, the production supplies only 10% of the market as most of the seafood is imported from other territories. The sector is based in marine waters (net cages), while the freshwater (ponds) achieves only 15% of the aquaculture production. The marine resources are Asian seabass (*Lates calcarifer*), Snappers (*Lutjanus campechanus*), Shrimp (*P. vannamei* and *P. monodon*), and mussels among other species. The freshwater species vary among varieties of Carps and Tilapias species (Fig. 14). The farmers have tried to improve their systems using Multi-Trophic Aquaculture Systems (IMTA) that recycle waste from one organism to be used by another species in culture (Shen et al., 2021).

The productive sector is managed by the Singapore Food Authority (SFA) and plays a relevant role in promoting domestic fish consumption, regulating the culture farms, and helps improving technology. The SFA has implemented biosecurity systems and best practices for better management, as such, farms are licensed and use vaccines to prevent diseases. The economy also manages educational institutions, and higher education on aquaculture and fish biology, for research into different aquaculture areas such as breeding selection, genomics platforms, developing molecular methods for gene resistance, and fish reproduction among other areas (Shen et al., 2021).

Some of the challenges that face the Singaporean aquaculture sector, is the incorporation of technology to facilitate and improve current systems. At present, most of the aquaculture is produced by small-scale and low-tech farms. From the environmental point of view, Singapore needs to invest in technology to prevent and control better natural events such as harmful algae blooms (HAB) that caused big mortality in marine resources.

From the antibiotic use perspective, Singapore banned the use of TC, CTC, and OTC, being the only economy that does not use OTC in aquaculture farms (Thiang et al., 2021). Although this economy has small aquatic production, they are conscious of AMR and its drawbacks, therefore, they launched Singapore's Strategic Action Plan (NSAP) that follows education, surveillance and

risk assessments, research, control and prevention of infections, and the optimization of AMU (Lim et al., 2020).

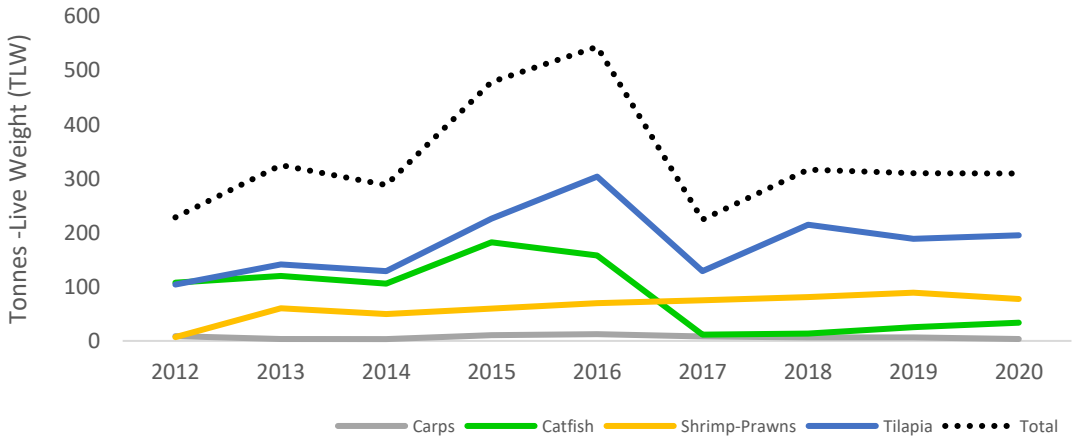


Figure 14. Singapore aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, Shrimps-Prawns and Tilapia, from 2012 to 2020. Source: FAO (2022c)

Thailand

Thailand aquaculture is founded on inland freshwaters and coastal marine waters gathered in pond nets systems. The main resources are the White leg Shrimp (*P. vannamei*) and Giant Tiger Prawn (*P. monodon*), Tilapia (*O. niloticus* and *Oreochromis mossambicus*), Carp (*Barbonymus gonionotus*), Catfish (*Clarias* sp.), and mussels' species (Oysters, mussels and clams). Aquaculture production for the relevant species of this report is presented in figure 15.

In 2013, there was a significant decline on Shrimp production caused by disease outbreak that mainly affected the Giant Tiger Shrimp. Despite the losses, Thailand still is one of the major contributors to shrimp aquaculture worldwide, where about 88% of the production is exported (Coyne et al., 2019). The most relevant exportations market are the USA, Japan, Canada and the European Union (EU) accounting with 146,710 tonnes - USD $1.42 billion (Booncharoen & Anal, 2021).

Concerning antibiotic use, it has been reported that antibiotics are used in Shrimp and Tilapia farms (Rico et al., 2013). About fourteen antibiotics has been identified where six, TC, OTC, amoxicillin (AMO), SLX-OR, sulphadimethozine and TRI, are the ones authorized by the Thai food and drug administration (FDA) (Lulijwa et al., 2020), other antibiotics such as ENR has been banned (Thiang et al., 2021). Since 2015 Thailand began with domestic strategies for antimicrobial resistance, and it is possible to obtain some data about antimicrobial use in livestock (Coyne et al., 2019). In fact, this economy learned from the past and after applying better actions in shrimp farming, they reduced the use of antibiotics (Henriksson et al., 2020).

The Ministry of Agriculture and Cooperatives manages the Department of Fisheries (DOF) that regulates the fisheries and aquaculture sectors, the Fisheries Act 1947 is the main legislative instrument that regulates aquaculture and fisheries. They have worked to promote sustainable aquaculture practices through a reformation of the sector, the Agriculture Standards Act B.E. 2551(2008), the shrimp Code of Conduct (CoC), and the Good Aquaculture Practices (GAP) for marine Shrimp (TAS 7401-2014), the GAP and CoC are necessary standards for exportation. Thailand also has invested in investigation to improve knowledge in diseases that can cause big outbreaks (Sampantamit et al., 2020).

Similarly, to other Asian territories, the Multi-Trophic Aquaculture Systems (IMTA) have been implemented as a good practice for improving management that forms a self-cleansing system.

Some of the challenges that the productive sector faces, are the environmental impact caused by the shrimp production which degraded habitat, for instance, the poor water quality and eutrophication triggered by the excess nutrients present in the water.

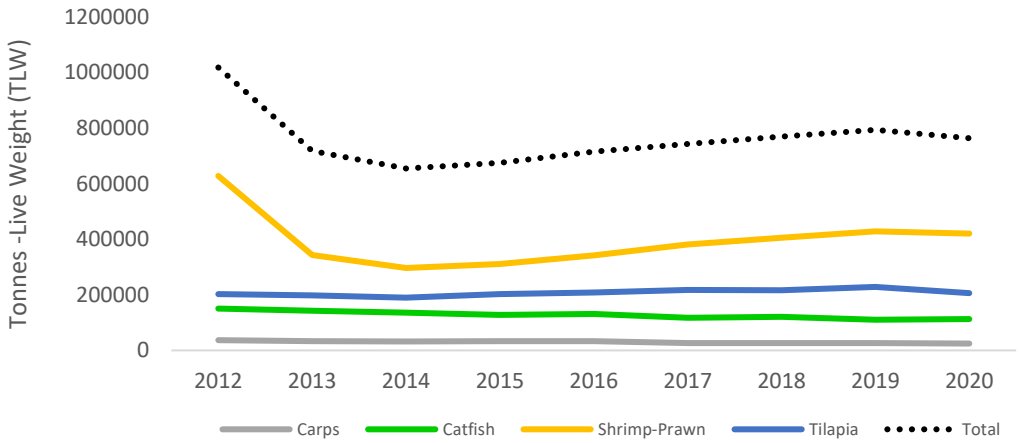


Figure 15. Thailand aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, Shrimps-Prawns and Tilapia, from 2012 to 2020. Source: FAO (2022c)

The Philippines

The aquaculture production in 2021 was 2,246.32 thousand metric tons, constituting 52.8% of total fisheries production, the production occurs in marine, fresh, and brackish waters. The culture systems varied from ponds, cages, and pens.

The main species are Milkfish (*Chanos chanos*) with 446.38 thousand metric tons, followed by Tilapia (six farmed species), 340.07 thousand metric tons which mean 11.8% of increment and represent 8% of the total fisheries, and Prawn & Shrimps (six farmed species) where the production reached 42.26 thousand metric tonnes (Fig. 16). These main species comprised 91.38% of the production. Other cultured species include seaweeds and various types of fish (Tahiluddin and Terzi, 2021; PSA 2021).

According to the Philippines Statics Authority (BFAR, 2019), aquaculture production and fisheries are consumed locally as the main source of protein intake (12%) by the population, consuming 37 kg/year. The aquaculture sector provides employment (49%) and where gender participation is very relevant.

The main challenge for this economy varies from disease outbreaks to water quality, among others. The diseases that affect Tilapia are mainly cause by *Streptococcus, Aeromonas* and *Pseudomonas* and in Shrimps bacterial and virus diseases e.g., WSD, WDF, EMS, HPM are presented. Regarding the water quality; degradation due to eutrophication boosted by high temperatures that also creates favorable conditions for Harmful algae blooms is the main problem (Tahiluddin and Terzi, 2021).

Veterinary drugs are prescript by a Licensed Veterinarian, and the use of antibiotics is under regulation (Karunasagar, 2020). This economy has shown a commitment to the complete removal of use of CLO and NF, both banned antibiotics (Lulijwa et al., 2020; Karunasagar, 2020). This economy holds the Philippines Action Plant to Combat Antimicrobial Resistance: One Health Approach (PNAP) which was established in 2015, and which are stated 7 main strategies for the aquaculture sector (Regidor et al., 2020). There is also a Domestic Residues Control Program (NRCP) that supervises drug use and residues in aquatic organisms, especially for those aquatic products with economic importance such as Tilapia and Shrimp. As a part of the program, a

survey was conducted to evaluate the status of AMU on Shrimp and Tilapia, and where no antibiotics were detected on registered farms as there is farmers' awareness about AMU and banned drugs (Regidor et al., 2020).

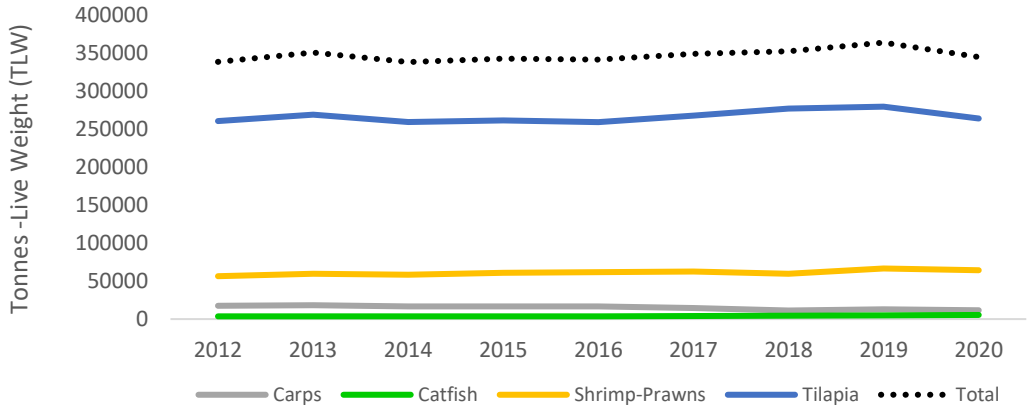


Figure 16. The Philippines aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, Shrimps-Prawns and Tilapia, from 2012 to 2020. Source: FAO (2022c)

Viet Nam

Currently is the fourth aquaculture producer economy with 4.4 million tonnes of production (Fig. 1). Aquaculture is one of the most relevant economic sectors for this economy (Dang et al., 2020).

In 2020, the aquaculture sector account 54% of seafood products, is a small-scale culture where the productions are based on ponds, cages cultured in estuarine and coastal waters, and cages that covers 260 thousand hectares destinated for mariculture (Minh-Thu et al., 2021). The sector is one of the most relevant economic activities (Coyne et al., 2019)

The farming species include Carps (*C. carpio*), Catfish (*Platydoras armatulus*), Tilapia (undetermined species) (Fig. 17), molluscs, lobster and snails.

Viet Nam Is the third largest Shrimp and Prawn producer, mainly White leg (*P. vannamei*) and Giant Tiger (*P. monodon*), respectively. Shrimp production is mostly exported (~94%), while Catfish is for both markets, domestic and worldwide (Coyne et al., 2019).

Some issues that affect the sector are management, diseases, over-carrying capacity, and pollution. Aquaculture is still a small-scale production mainly due to the need for better technology for improving systems, equipment, the value of chains, and seed source among others (Minh-Thu et al., 2021). The economy has established regulatory systems for veterinary compounds, feed, quality products, and environmental protection. The Ministry of Agriculture and Rural Development (MARD) manages the use of chemicals, they provide training and control quality feed and seeds (Tran et al., 2021)

Regarding antibiotics, it has been described it uses in Shrimp and Catfish (Pangasius) farms, seventeen antibiotics have been reported including different classes such as tetracyclines (TC), FLO, and quinolones, among other classes, and most of them are applied to Tilapias farms (Rico

et al., 2013). CLO and NF are banned products (Lulijwa et al., 2020). The use of antibiotics for growth promotion is also banned since 2018 (Coyne et al., 2019), and ENR, TC, and CTC are not allowed in aquaculture farms (Thiang et al., 2021).

Viet Nam is part of the Asian economies that have implemented a plan to tackle AMR, under the Ministry of Health (MoH) the "Viet Nam ´s Action Plan (NAP) on combatting drug resistance", and a Domestic Steering Committee on Prevention of AMR were created with the main aim of mitigate antibiotic resistance (ABR) in humans by decreasing antibiotic use in aquatic farming species (Dang et al., 2020)

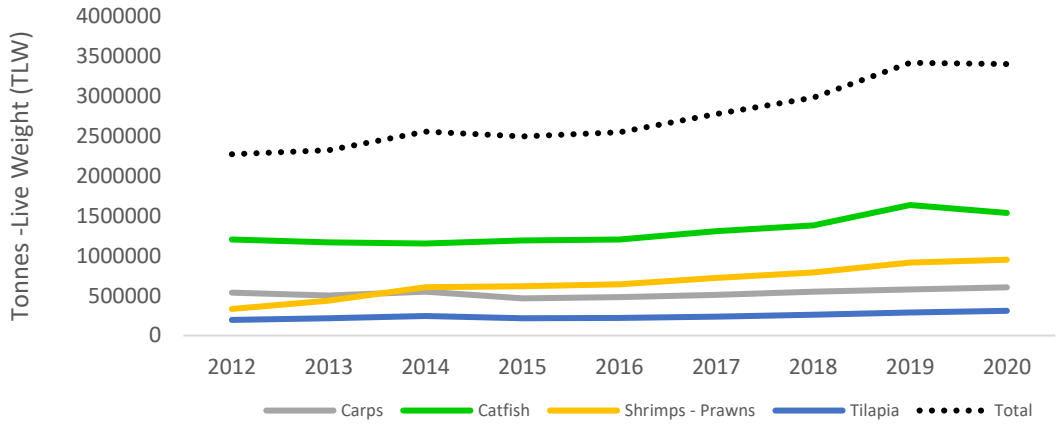


Figure 17. Viet Nam aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, Shrimps-Prawns and Tilapia, from 2012 to 2020. Source: FAO (2022c)

EAST-ASIA ECONOMIES

This region is led by the biggest aquaculture producer and the dominant carps' producer; therefore, Carps are the largest aquatic resource produced by this region (Fig. 18), is also an important animal protein source on people's diet for many Asian economies. Carps are the most common cultured species worldwide, globally there are 29 farmed species that contributed with fish fin farming (Miao & Wang, 2020).

Shrimp-Prawn are the second important aquatic resource for this region, its importance lies on worldwide trade, the main farmed species are the Giant Tiger Prawn, *Penaeus monodon,* and the Whiteleg Shrimp, *Penaeus vannamei*. Worldwide, shrimp-prawn production is led by People's of Republic of China (Miao & Wang, 2020).

Tilapia has the third place as aquatic resource in the region. Tilapia is the second-most important finfish farmed in East Asia. Tilapia is originated from Africa, but in this region its farming has grown faster than other aquatic species, consolidating this farming as an important aquatic

resource (Miao & Wang, 2020). People's Republic of China is the most important Tilapia producer in this region.

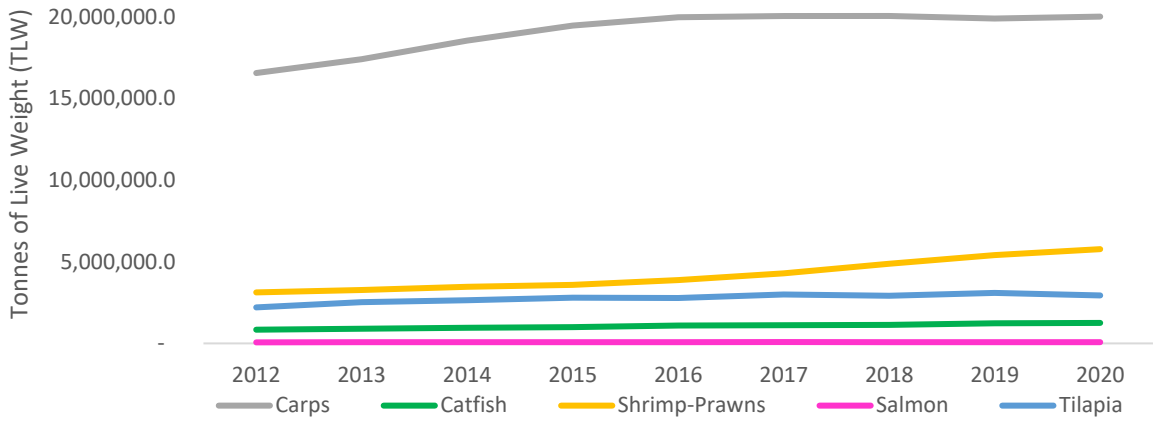


Figure 18. East Asia aquaculture production (Tonnes of Live Weight - TLW) for relevant species from 2012 to 2020. Source: FAO (2022c)

People's of Republic of China

China has been the main aquaculture producer in the world for many years, contributing with 60% of the global aquaculture. Until 2017 the sector was sustained in 7.45 million hectares (Mha) concentrated in rural areas and managed by farmers with limited education (Wang et al., 2020). The aquaculture is produced in fresh and marine waters, ponds is the main systems used in inland waters, while in marine water are common floating rafts and net-cages.

The most common resource includes molluscs, seaweeds, crustaceans and finfish. Some of the farming species are Catfish (three species), Carps (six species), Tilapia (*O. niloticus*), Shrimp and Prawns (six species), and salmonids (Fig. 19). China es the major producer of farmed Carps being distinguished as the oldest aquaculture recorded globally, 2,500 years ago, and in terms of value and production is the most valuable species (Miao & Wang, 2020). China is also the biggest producer of farmed shrimp with a total of 32% of the global production in 2018 (Miao & Wang, 2020).

This economy is the biggest aquaculture producers and the antibiotic consumer of the region. Antibiotics has been detected on soil and rivers, where the most polluted areas have been identified as Beijing, Tiajin-Hebei, Dalian, Qingdao and Tangshan. Fourteen antibiotics has been identified in aquaculture farms among CLO, macrolides, sulfonamides and fluoroquinolones (Shao et al., 2021; Zhang et al., 2021). While Lulijwa et al. (2020) report 33 types of antibiotics in aquaculture farms, mostly used in shrimp and catfish, this economy presents valuable information on antibiotics resistance studies and reviews.

There is exist regulation over drugs, although situation is complex, the Environmental Protection Law concerns to aquaculture, stipulates that fisheries authorities are responsible of drugs administration (FAO, 2022b). In effect, the banned veterinary substances are available, but regulated by the Regulation on the Administration of Veterinary Drugs, Article 39, Chapter 6 (Karunasagar, 2020).

This economy holds an AMR program, the People's of Republic of China Action Plan on AMR with a Surveillance Program headed by the Ministry of Agriculture and Rural Affairs (MARA), where 14 fish species are monitored (Yuting et al., 2020).

The economy has invested in aquaculture development, improving training, extension services programs, collaborative alliance. The sector is managed by The Fisheries Law of the People's Republic of China which encourages advances in technologies and skills for farmers. The educational institutions work together for improving aquaculture production, breeding programs, and farming technologies among other areas. There also exist organizations such as the Chinese Aquaculture Association that provide scientific guidance and participate in decision-making, economic breeding methods, and species to grow (Wang et al., 2020; Shao et al., 2021).

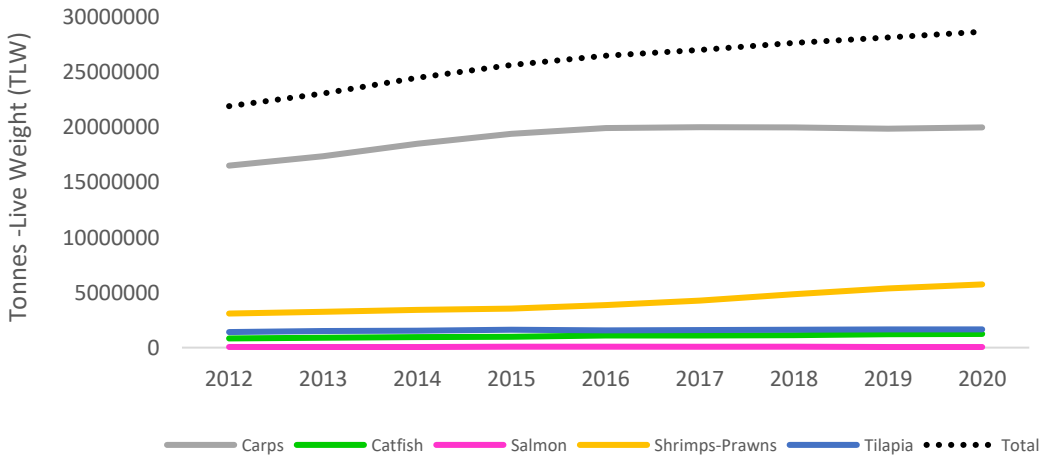


Figure 19. People's of Republic of China aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, Salmon, Shrimps-Prawns, and Tilapia, from 2012 to 2020. Source: FAO (2022c)

Hong Kong, China

The aquaculture sector includes ponds culture and marine fish culture. The cultured resources are Tilapia (*O. niloticus*), Carp (five species), Catfish (*Clarias fuscus*) (Fig. 20), and Mullet, which are most of the time mixed in ponds as polycultures (95%). The ponds production is mainly located in the North-Western territory of Hong Kong China, the total fishponds production was 2,278 tonnes valued in Hong Kong Dollar (HKD) $51.74 million in 2019 (~USD $6.59 million), while the total marine fish culture was 889 tonnes valued at HKD $72 million (~USD $9.18 million) (Hong Kong China: The Facts, 2020).

Most of the marine farms are small farmers based on family groups that counts with two rafts (~ 304 m^2). This type of culture is regulated by the Marine Fish culture Ordinance (Cap. 353), seizing a total area of 209 hectare (AFCD, 2022).

The economy introduced in 2005 the voluntary Accredited Fish Farm Scheme (AFFS) with main goal of enhance high environmental hygiene standards and quality products. The program includes analysis of residues for food safety exportation standards, training, technical support, diseases diagnosis and viral screening services. One of the main aims is enhance biosecurity measures for “Good Aquaculture practice Program” to manage and monitor AMU and AMR in local farms.

One of the challenges that Hong Kong, China, faced is Red Tide bloom, therefore, the economy implemented a monitoring program where water column sampling is taking frequently to prompt alerts to aquaculture farmers. Additionally, they manage water quality monitoring programs that in some cases provide real-time data that helps to raise early alerts. Other issues are disease outbreaks caused by bacteria or protozoa, but the economy implemented the Fish Health Program, the program consist in regular visits to farms, assistance in diagnosis and treatment (AFCD, 2022).

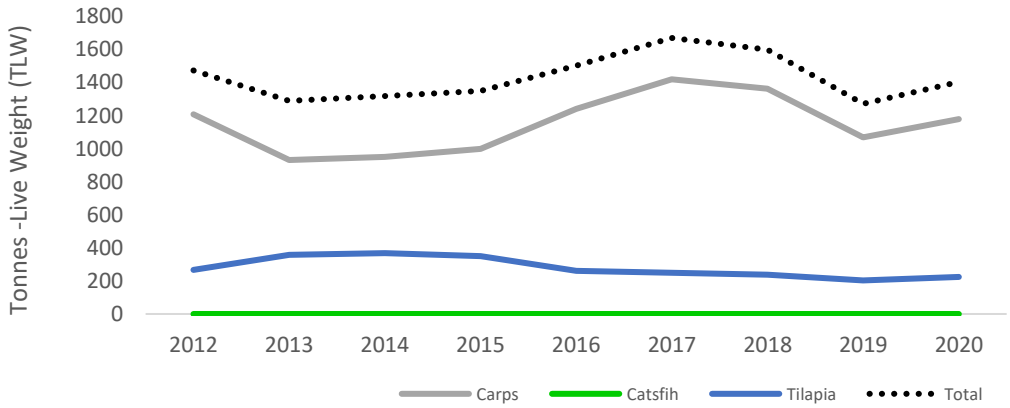


Figure 20. Hong Kong, China, aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, and Tilapia, from 2012 to 2020. Source: FAO (2022c)

Japan

The aquaculture comprises a wide range of resources including finfish, crustaceans, bivalves and seaweeds. The production is generated in marine and fresh waters, and it is mainly consumed in the domestic market, seaweeds play a relevant role in the seafood resource. Some of the culture resources are Carps (*C. carpio* and *Carassius carassius*), Salmon (*O. kisutch, O mykiss*), and Prawn (*Marsupenaeus japonicus*) (Fig. 21) are produced in the economy but are not consumed in big amounts. In 2018, Japan produced 4.2 million tonnes of seafood (i.e., fish, molluscs, and crustaceans) that is traduced in USD $13,775.7 million, where 38% coming from aquaculture production, contributing to 202,430 jobs employment (OECD, 2021). Although, Japan produced aquaculture goods, is, for instance, the second biggest shrimp importer (Miao & Wang, 2020).

Nevertheless, the sector has been affected by natural disasters (i.e., tsunamis) that caused an abrupt decrease in aquaculture production. Other relevant factors are environmental issues and socio-economic reasons. Regarding disease issues, vaccines have become available reducing disease damage to a 4%. While the use of the antibiotic has decreased significantly. From the environmental perspective, Japan faces similar issues to other economies such as the bloom of harmful algae and eutrophication. But the social factor has affected the sector as well, reducing the considerable workforce (Watanabe & Sakami, 2021).

In relation to antibiotics use, Japan is one of the economies where antibiotics consumption decreased considerably to zero consumption according to Lulijwa et al. (2020). The aquaculture sector is managed by the Fisheries Law (1949) which demarcated the rights for the activity and ensure sustainable production. Japanese markets produce certified products ~500,000 tonnes (fisheries and aquaculture).

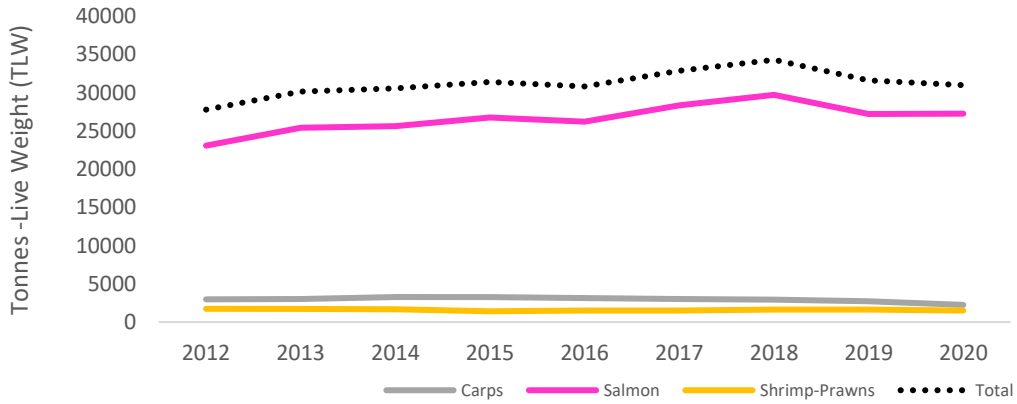


Figure 21. Japan aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Salmon and Shrimps-Prawns, from 2012 to 2020. Source: FAO (2022c)

Republic of Korea

Aquaculture happens in fresh and marine waters, and covers various species where seaweeds take the first place in production with 1.2 billion metric tonnes; followed by mollusk with 330,000 metric tonnes and finfish with 85,000 metric tonnes (FAO, 2018; Park et al., 2018). The production for the selected species for this report are Carps (various species), Catfish (four species), Salmon (*S. salar, O. masou,* and *O. mykiss*), Shrimp-Prawn (various species) and Tilapia (*O. niloticus)* is presented in figure 22.

Seafood production is mainly for domestic consumption, and part of the production is exported to other territories. The major exported species are tuna, squid, oysters, crabs, wakame, and clams among others.

The aquaculture sector in Korea met a series of challenges such as disease outbreak. For instance, the shrimp industry must deal with emergence of AMR. The use of antibiotics is regulated by the economy but the accuracy on its usages, data and sales, is hard to obtain in the publicly available information. Diseases such as WSSV and Hypodermal and Hematopoietic Necrosis Virus (HHNV) causes significant losses to the industry (Han et al., 2020). While Tilapia is strongly affected by *Edwardsiella anguillarum,* a lethal bacterium that cause big mortality in this species worldwide and has been detected in Korean farms (Oh et al., 2020).

The Ministry of Food and Drugs Safety (MFDS) regulates the drugs administration (all chemical components including antibiotics), for veterinary uses 52 compounds drugs have defined the tolerance drug concentrations, the Maximum Residue Limit (MRL). There is also exist a surveillance program to identify residues in aquatic products, which is led by the Domestic Institution of Fisheries and Science (NIFS) and the MFDS (Kang et al., 2018). A few studies have been conducted to investigated antimicrobial residues in aquatic food (Kim et al., 2017; Kang et al., 2018), and where OTC showed the highest rate of consumption (Kim et al., 2017).

Another big concern are HABs not only because affects aquaculture, but also strongly affect human health. The combination of factors such as natural events, intensive fish aquaculture and eutrophication caused environmental degradation. Facing this powerful challenge, the Republic of Korea implements Integrated Multi-Trophic Aquaculture (IMTA) as a possible solution to achieve economic and environmental sustainability (Park et al., 2018).

One of the latest challenges that aquaculture producer confronted, were important losses caused by COVID. In respond to this important issue, the economy invested Korean Won (KRW) $3 billion (~ USD$ 2.4 million) for providing economical support to aquaculture farmers and fisheries business to recover their production and business (OECD, 2020).

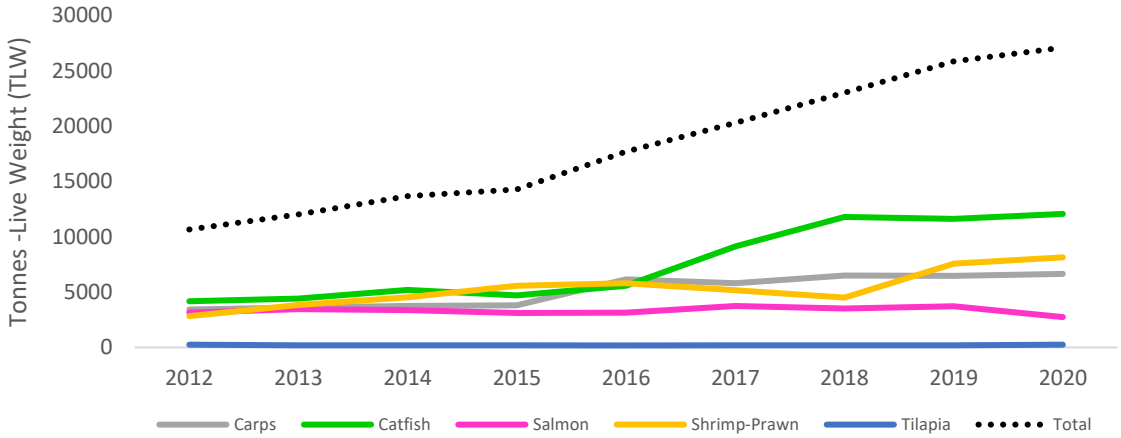


Figure 22. Republic of Korea aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, Salmon, Shrimps-Prawns, and Tilapia, from 2012 to 2020. Source: FAO (2022c).

Chinese Taipei

Aquaculture is based on fresh and marine farms. The species produced varies from fish (e.g., Tilapia, Milkfish and Grouper), mollusks (e.g., oyster, clams and abalone), crustaceans (e.g., Shrimp and mud crab) among other fresh and marine water species. Tilapia (*Oreochromis* sp.) is the most important farmed species reaching about 70,000 metric tonnes, the market is mainly domestic, but part of the production goes to abroad markets as well (Liao et al., 2020). There are six Carps species in culture and five species of crustaceans between shrimp and prawns. Though, the aquaculture production for the resources has been declined since 2012 (Fig. 23).

As many other economies, diseases outbreak is one of the main challenges for farming species, bacterial infections affected several species during farming, such as Tilapia, Catfish, Shrimp, and even wild fish. The increment in water temperature and the extreme weather (e.g., tifon) exacerbates the presence of diseases (Liao et al., 2020).

The Chinese Taipei authorized some antibiotics to be used in aquaculture including OTC, ERY, FLU, SLX, sulfamonomethoxine, and lincomycin (Lai et al., 2018). In a comprehensive study conducted by Lai et al. (2018), diverse antibiotics and other toxic substances were identified in areas surrounding aquaculture ponds. While other recent studies detected OFX, CIP, and FLU, among other antibiotics such as ENR that has been banned in aquaculture areas (Thiang et al., 2021).

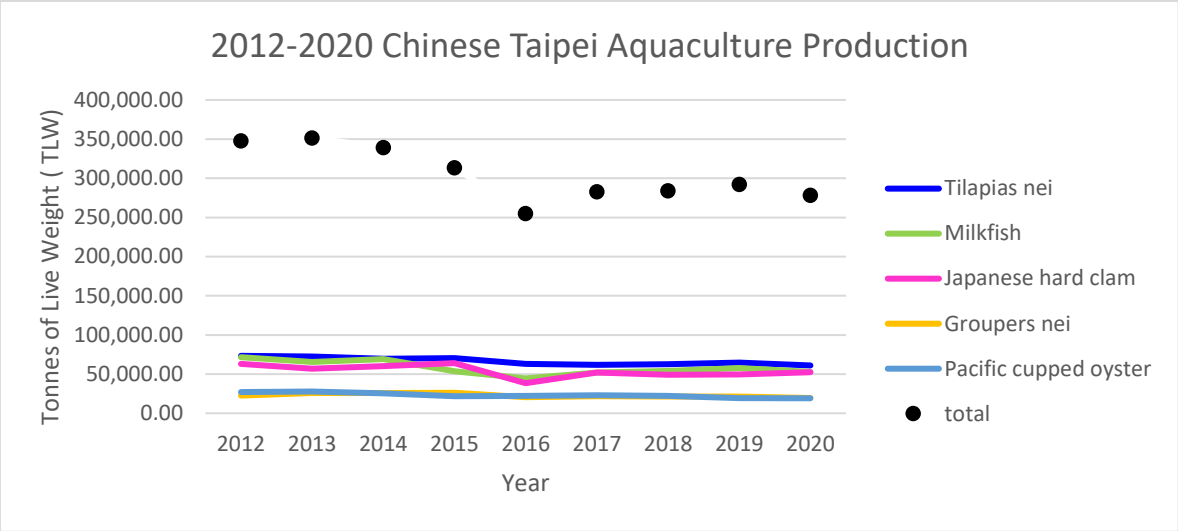


Figure 23. Chinese Taipei Aquaculture Production for relevant species Tilapia Nei, Milkfish, Japanese Hard Clam, Groupers Nei, and Pacific Cupped Oyster, from 2012 to 2020. Source: FAO.

EASTERN EUROPE ECONOMIES

This European region carries only one APEC economy where aquatic resources are mainly finfish such as Carps and Salmon, as it shown in figure 24. In the recent SOFIA Report (FAO, 2022a), was states Russia in the top-ten producers (tenth place) in terms of exporting aquatics products by value in 2020.

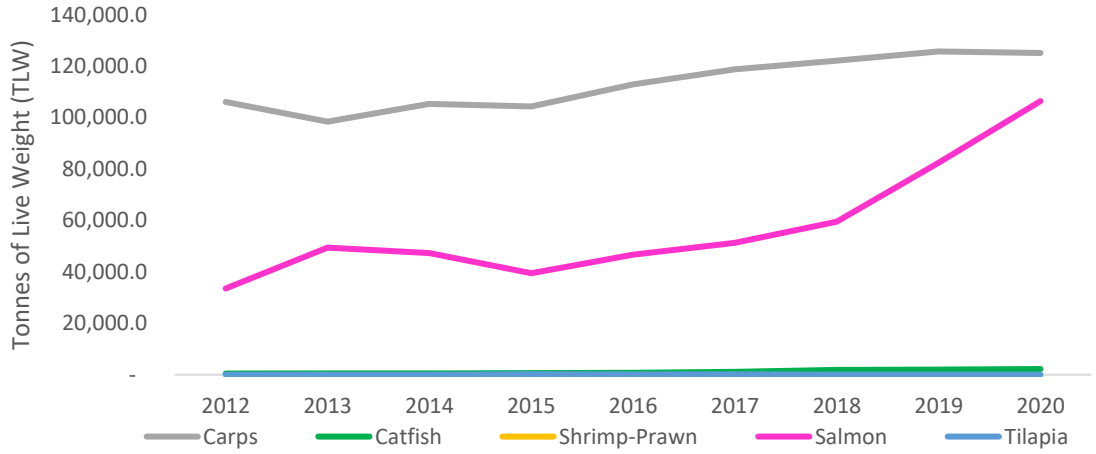


Figure 24. Easter Europe aquaculture production (Tonnes of Live Weight - TLW) for relevant species from 2012 to 2020. Source: FAO (2022c)

Russia

The salmon industry is based on two species *S. salar* and *O. mykiss,* reached 27 thousand tonnes in 2021 growing a 29% in comparison with 2020, the salmon production for the last eight years is presented figure 25. Other fish species includes Carps (four carps' species), Catfish *(Ictalurus punctatus),* and Tilapia (undetermined species) (Fig. 25). While another species as Sturgeon is dominant in commercial culture for caviar production, accounting with 3,871 tonnes in 2017 (Vasilyeva et al., 2018).

As Russia is in the artic region, a unique ecosystem, the Russian Aquaculture Group has bet on sustainable production based on certified products, antibiotic-free, hormone-free, and Genetically Modified organisms- free (GMO-free), fair competition, and market transparency.

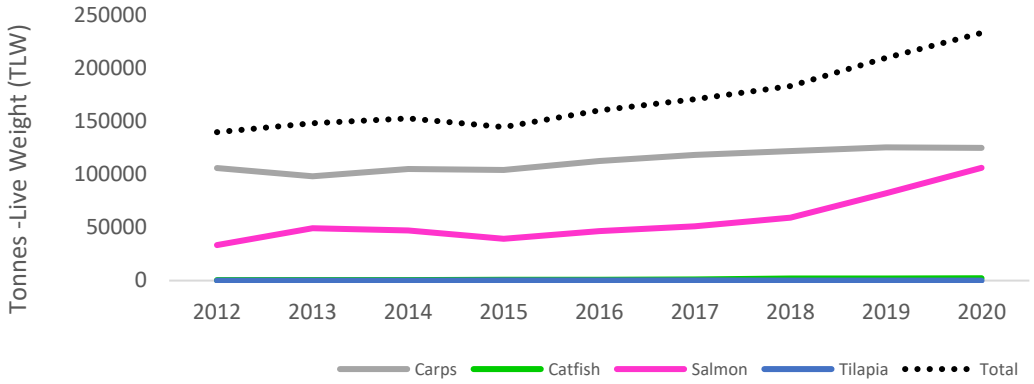


Figure 25. The Russia Federation aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Catfish, Salmon and Tilapia, from 2012 to 2020. Source: FAO (2022c).

OCEANIA

The Oceania zone includes only three APEC economies Australia, Papua New Guinea and New Zealand. The aquaculture production is dominated by Salmon produced by Australia and New Zealand, which are the dominant aquaculture producer on the region. The second aquatic resource are Shrimp-Prawns produced by Australia. While Papua New Guinea manages small aquaculture production and where most of the farmers are small-scale producers, little information is available from this economy.

This region hosted one of the unique cases of aquaculture producer where no antibiotics is applied on salmon farming, New Zealand.

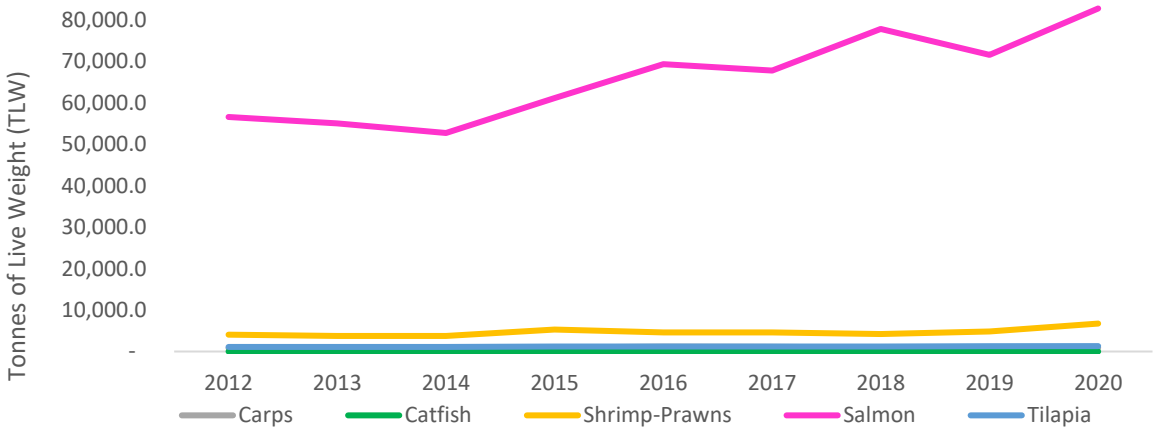


Figure 26. Oceania aquaculture production (Tonnes of Live Weight - TLW) for relevant species from 2012 to 2020. Source: FAO (2022c)

Australia

Australia holds a small aquaculture industry that is in constant growth. The main aquaculture production is exported, they have a variety of products that are still at low production levels by world standards such as algae, freshwater crayfish, mussels, clams and scallops. Aquaculture production is in fourth place after poultry, pigs and cattle, the sector is currently dominated by Atlantic salmon (55%) with Australian Dollar (AUD) $191 million (~USD $132 million) of exportation in 2020 and 67,133 tonnes of live weight (Fig. 27) (Brown et al., 2020).

The latest Australasian fisheries and aquaculture report (Brown et al., 2020), showed that the aquaculture sector increased by 10% to AUD $1.60 billion accounting for 51% of total Gross Value Production (GVP). The volumes of aquaculture increased by 11% to 106,139 tonnes, accounting for 38% of the total volume.

The main aquaculture producers' states are Tasmania, which produces salmon with AUD $931 m and 69,519 tonnes in 2020; the state of Queensland is the main producer of shrimp-prawns (six species) and barramundi with AUD $161 m and 9,573 tonnes in 2020; and the state of South Australia produces southern Bluefin Tuna that reached AUD $229 m (~USD $) and 17,472 tonnes in the same year (Brown et al., 2020).

Regarding employment, the aquaculture sector provided 5,000 employments in 2014 increasing to 7,000 people in 2020.

The aquaculture production is subjected to the Commonwealth legislation, the aquaculture industry is coordinated by the Aquaculture Council (NAC). As Australia manages territories, every state manages separately legislation for the activity. The Commonwealth Agriculture and Veterinary chemicals (Administration) manages the use for drugs (FAO, 2022b)

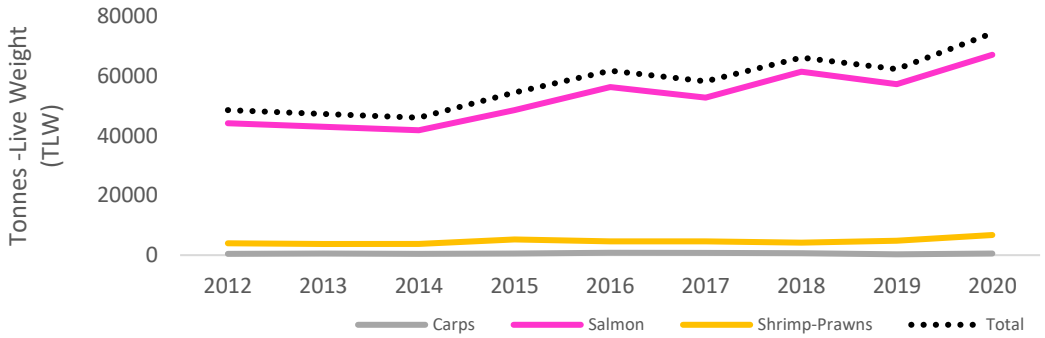


Figure 27. Australia aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Salmon and Shrimps-Prawns, from 2012 to 2020. Source: FAO (2022c)

Papua New Guinea

The aquaculture production occurs mainly in freshwater and the sector remains in small-scale as the farmers has poor access to quality fingerlings, feed, lack of skill and poor infrastructure. The production is mainly for local consumption as fish is the main protein source, for farmers' incomes is a secondary opportunity. Tilapia is the main aquatic resources, the farmed happened in earthen ponds and is produced from about 60,000 small-scale farms but the production still low in comparison with other Asian economies. The economy has prioritized the development of fish farms as the sector provides food security, allow rural development, and provide incomes. As part of the aquaculture development sector, Papua New Guinea has worked in collaboration with Australia by conducting research, farms strategies and training to farmers (ACIAR, 2021).

Interestingly, 1% of the fish farmers are households' women. Although, they play a relevant role that is unknowledge because they care for the fish, provides the meal, and see the farming with responsibility (ACIAR, 2021).

The total aquaculture production reached 1,800 tonnes in 2020 for the selected species in this report, Tilapia (*O. niloticus*) is the most relevant culture species with 1,300 tonnes in 2020, followed by Carps (*C. carpio*), Salmon (*O. mykkis*), and Shrimp-Prawns (*P. monodon*) that decreased since 2015 (Fig. 28). Other species in culture are mussels and seaweeds, being seaweeds the main aquaculture resource (FAO, 2021).

The sector is managed by the Fisheries Management Act (1998) and the Fisheries Management Regulations (2000) that promotes sustainability. This economy is subscribed to the FAO Code of Conduct for Responsible Fisheries, which includes aquaculture (FAO, 2022b).

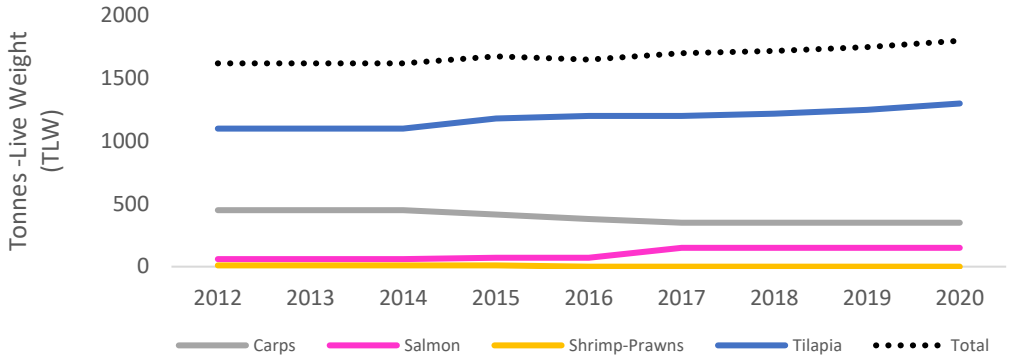


Figure 28. Papua New Guinea aquaculture production (Tonnes of Live Weight - TLW) for relevant species Carps, Salmon, Shrimps-Prawns and Tilapia, from 2012 to 2020. Source: FAO (2022c)

New Zealand

The aquaculture sector is based in fresh and marine waters, where the commercial production occurs in about 40% of the allocated hectares for farming. This sector has been increasing considerable contributing significantly to the economy and employing about 3,000 people in 2018 (Stenton-Dozey et al., 2020).

Main species in culture are salmon (Fig. 29) and mussels. The Green-lipped mussels (*Perna canaliculus)* occupied 86% of the total production, and the Chinook salmon (*O. tshawytscha*) occupied 12% of the production (Stenton-Dozey et al., 2020. This economy is the major mussel producer in the region with 88,200 tonnes (FAO, 2020). Salmon is exported mainly to USA, Australia, China, Japan, Europe, Canada, Singapore and Thailand (Aquaculture New Zealand, 2022). The New Zealand salmon industry and the mussel industry has been rated as the only "Best Choice" for sustainable seafood in the planet (Aquaculture New Zealand, 2022). Other species in culture include oyster, abalone, and scallops.

New Zealand manages sustainable aquaculture with the priority of the health ecosystem minimizing 100% farming effects. Fortunately, they own a unique situation, given the lack of disease outbreaks is the only economy that does not use antibiotics in salmon production. The salmon industry leads biosecurity management, while oysters and mussel are improving their practices in this field. The aquaculture industry ensures the safety, quality, and traceability of the products to assures consumers' confidence (Sustainable Report, 2021).

The marine aquaculture activity is managed by the Resource Management Act 1991 (RMA) which promotes sustainability, and where the regional council manages responsible planning. The economy also operates high biosecurity standards to reduce the risk of diseases and harmful pests under the Biosecurity Act 1993 (FAO, 2022b).

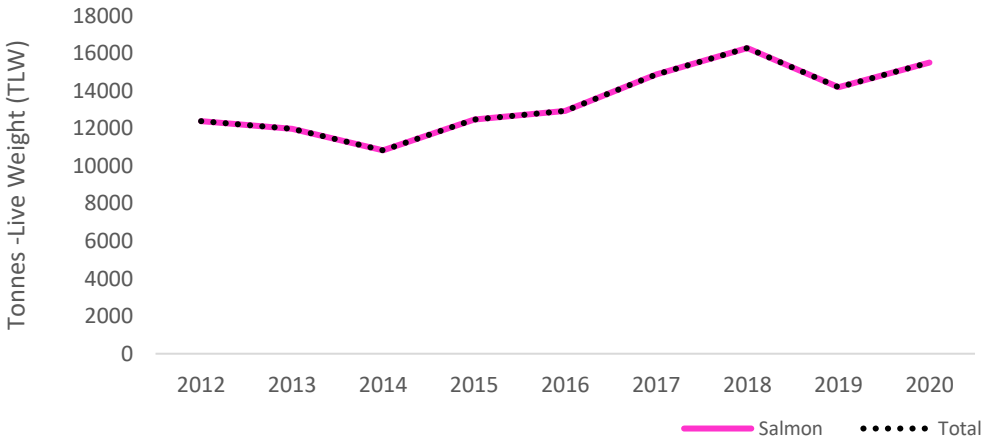
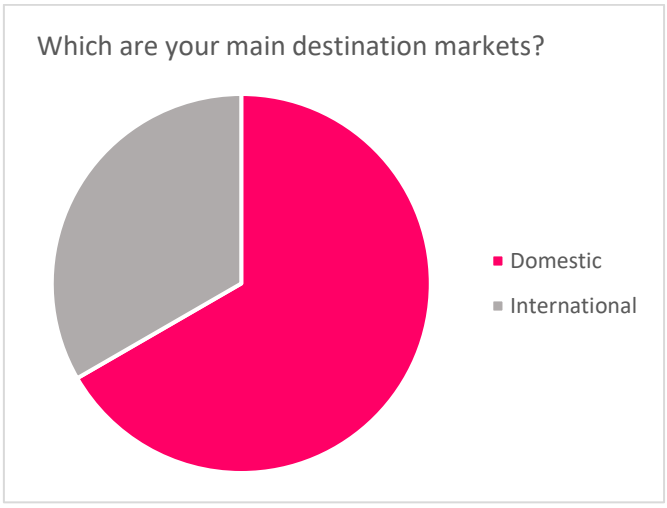


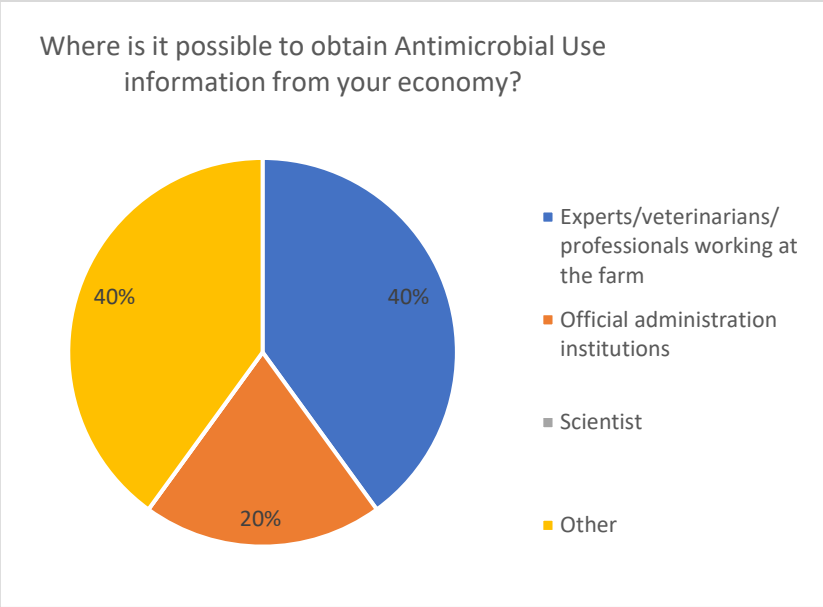
Figure 29. New Zealand aquaculture production (Tonnes of Live Weight - TLW) for a relevant species, Salmon, from 2012 to 2020. Source: FAO (2022c)

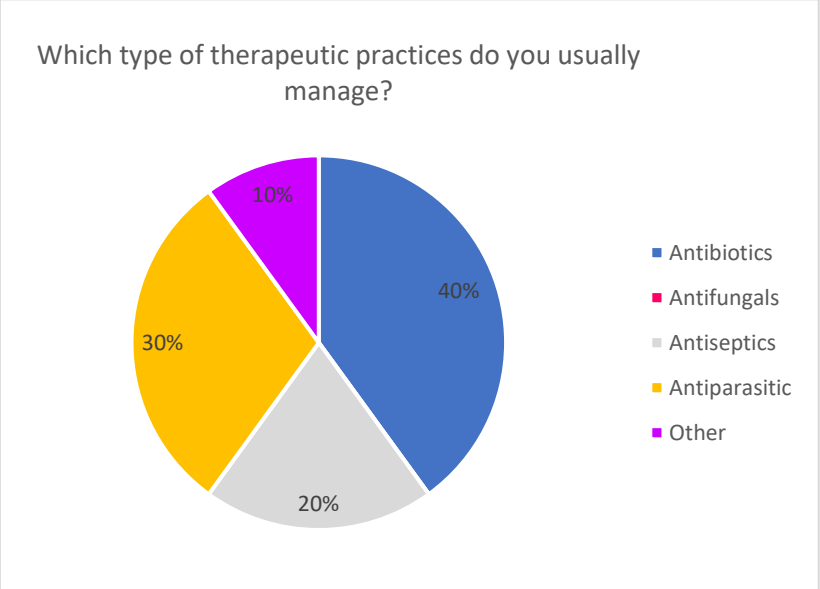
Results from the workshop survey

As a part of the implementation of this project, a three-day workshop was done on July 27, 28 and September 7. During the webinars a survey throughout the zoom system was performed to the participants in order to gather more information regarding the use of antimicrobial in aquaculture in the APEC economies. In total were 2 surveys, one performed on July 28 and the second one on September 7, the participants' economies were Australia, Canada, Chile, People´s Republic of China, Japan, Malaysia, Mexico, New Zealand, Peru, Chinese Taipei, Thailand, United States of America, and Viet Nam.

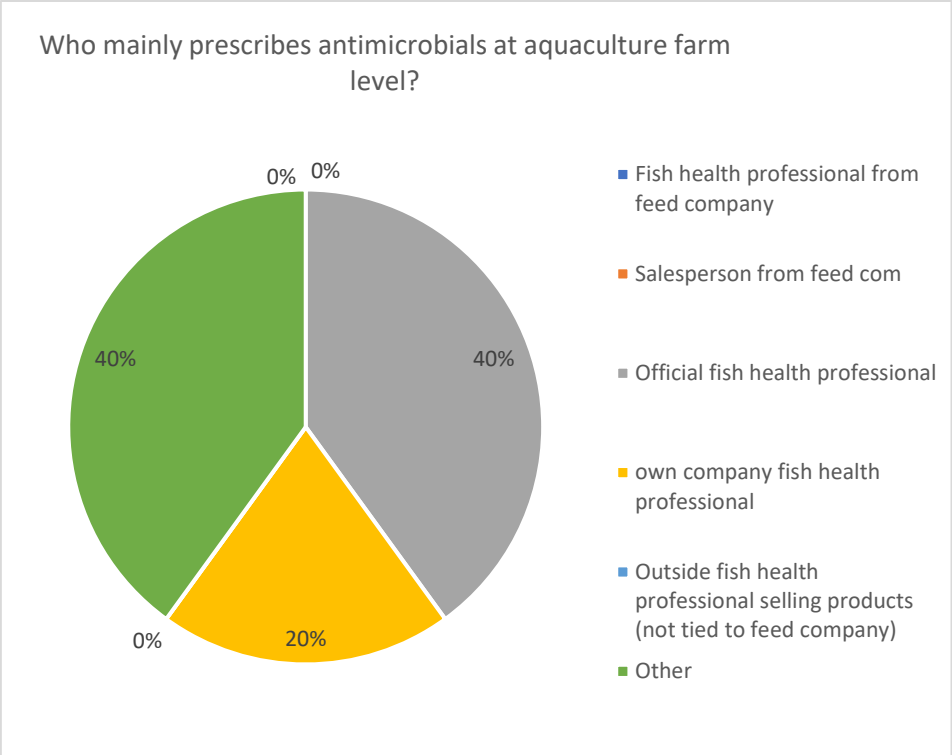
The following graphics represent the summary of responses obtained to each of the questions by the participants economies.

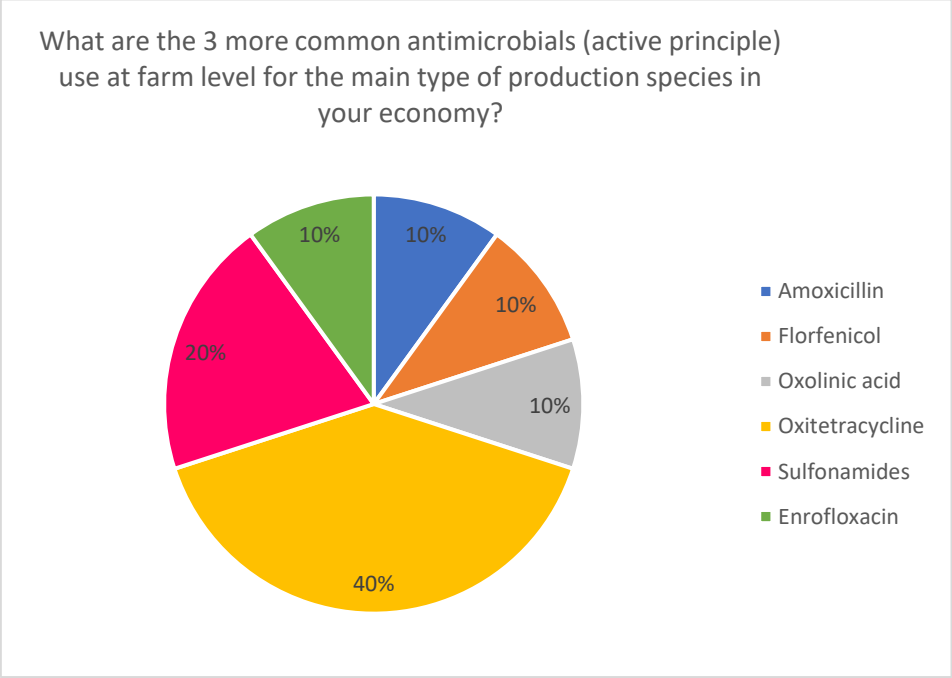


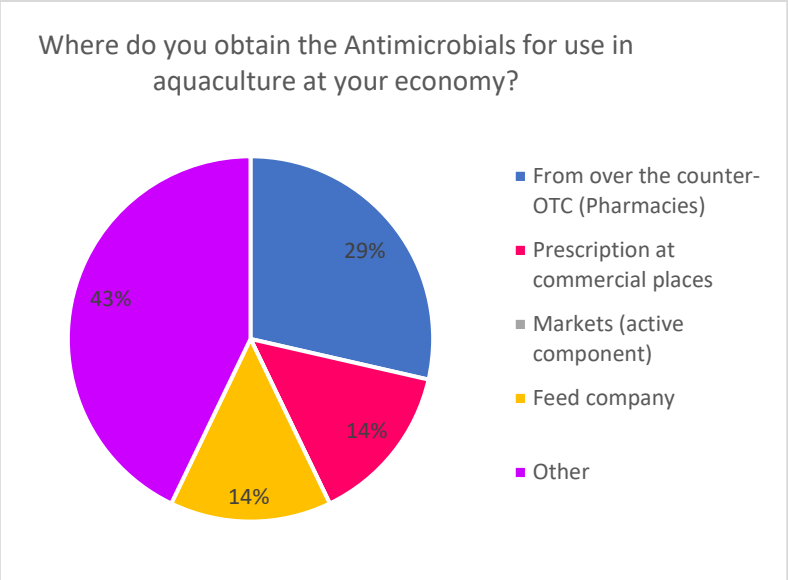

Where is it possible to obtain Antimicrobial Use information from your economy?
40%
40%
20%
Experts/veterinarians/ professionals working at the farm
Official administration institutions
Scientist
Other


Which type of therapeutic practices do you usually manage?
10%
40%
30%
20%
Antibiotics
Antifungals
Antiseptics
Antiparasitic
Other

APEC


Who mainly prescribes antimicrobials at aquaculture farm level?
0%
0%
40%
40%
0%
20%
Fish health professional from feed company
Salesperson from feed com
Official fish health professional
own company fish health professional
Outside fish health professional selling products (not tied to feed company)
Other


What are the 3 more common antimicrobials (active principle) use at farm level for the main type of production species in your economy?
10%
10%
10%
10%
20%
40%
Amoxicillin
Florfenicol
Oxolinic acid
Oxitetracycline
Sulfonamides
Enrofloxacin



Final Conclusions

Among the selected species in this publication, some advantage and challenges for the aquaculture industry have been identified. In the case of Carps and Tilapia, both species have great culture potential beside adverse environmental conditions such as climate change, they are tolerant to temperature changes, resilient, has a low carbon-footprint as they can grow easily in co-culture (e.g., horticulture), and they can be produced with relatively low cost (Miao & Wang, 2020). Although shrimp culture is very vulnerable to disease and environmental changes, its demand and the worldwide market make shrimp a valuable aquaculture species. While the salmon industry is raising awareness for sustainable production due to consumers' pressure.

In general, small-producer economies faced similar challenges in the Asia Pacific region such as poor farming technology, disease outbreak, and environmental degradation. But the intensification of production can bring more disease outbreaks exacerbated by the climate change conditions, and with that an increment in antibiotics use (misuse and overuse), therefore; AMR, unless other actions will be taken. Recently, it was identified a correlation between warmer temperatures and a higher level of AMR levels in aquaculture, and where it was demonstrated that at a high temperature higher is the mortality caused by an increment in diseases (Reverter et al., 2020).

According to FAO (2022a), the aquaculture industry has grown at the expenses of the environment suggesting that sustainable aquaculture is the main key to moving forward and supplying global demand for aquatic food. Presently, the big aquaculture industry in Asia Pacific region is conscious about sustainability throughout all production chain as they are betting on healthy products, quality, animal welfare, environmental responsiveness, good practices, and certified products. Altogether, in response to consumers force that are willing to pay for a fair price and safety premium goods (Suzuki & Nam, 2018; Booncharoen et al., 2021; Sustainable Report, 2021; van de Braak, 2021; Ishihara et al 2022).

The Blue Transformation vision proposed by the FAO (2022) focus on environmental and social wellbeing, and nutritional and food security. Through sustainable aquaculture, where the expansion and intensification are essential under effective management, to respond to the global aquatic food demand.

Despite the fall in production in recent years in some of the economies, aquaculture production touched extraordinary records, and it is expected that will continue expanding. The sector has turned in the best way to provide food to the growing human population, as the main source of protein in some of the APEC economies and will enable to assist the 2nd goal of the United Nations, Zero Hunger.

Certainly, according to the last SOFIA FAO Report, the aquaculture sector would be the main source of animal protein for the world, and where de APEC economies play a relevant role as they provide the major aquaculture production. Notwithstanding, there are challenges that remain such as controlling diseases, pollution, and HAB, all together could be exacerbated by climate change and its drawbacks.

Regarding antibiotic use, there is a group of economies where the use of antibiotics is regulated by domestic agencies, therefore, data is available (i.e., banned products and allowed products). In other situations, the available data is quite inconsistent, most of the information available is based on surveys, reviews, or extrapolations that do not reflect the real antibiotic consumption by economies, which in turn reflects the complexity of the antibiotic use issues and can cause confusion. The most completely available data is reported by the World Organization for Animal Health, WHOA (2021). Thus, the evidence provided in this document reinforced the lack of information available for some economies and delivers an update of the data available for the APEC economies.

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