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Regional Consultative Workshop on

Antimicrobial Resistance Risk Associated with Aquaculture in the Asia-Pacific

Bangkok, Thailand, 4-6 September 2018

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Edited by

Eduardo M. Leaño
Senior Programme Officer
Network of Aquaculture Centres in Asia-Pacific
Bangkok, Thailand

Miao Weimin
Aquaculture Officer
FAO Regional Office for Asia and the Pacific
Bangkok, Thailand

Food and Agriculture Organization of the United Nations
Regional Office for Asia and the Pacific
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Preparation of this document

This publication documents the FAO-supported 'Regional Consultation on Antimicrobial Resistance Risk Associated with Aquaculture in the Asia–Pacific Region', which was jointly conducted by the Network of Aquaculture Centres in Asia-Pacific (NACA) and the FAO Regional Office for Asia and Pacific (FAO-RAP) from 4 to 6 September 2018.

The publication presents the background, objective, preparation process, expected outcomes and the main conclusions and recommendations from the regional consultation. The publication includes the seven country case study reports on the status of antimicrobial use in aquaculture and the efforts to manage the risks of antimicrobial resistance, which were contributed by national experts. A regional synthesis by an international consultant is also provided.

The publication was jointly prepared by officers at NACA and FAO.

Contents

Abbreviations and acronyms

AHPND	Acute hepatopancreatic necrosis disease
AM	Antimicrobial
AMR	Antimicrobial resistance
AMU	Antimicrobial use
API	Active pharmaceutical ingredient
ARG	Antimicrobial resistance gene
ASEAN	Association of Southeast Asian Nations
AST	Antimicrobial sensitivity testing
AVA	Agri-Food and Veterinary Authority (Singapore)
BAI-DA	Bureau of Animal Industry – Department of Agriculture (Philippines)
BFAR	Bureau of Fisheries and Aquatic Resources (Philippines)
BNP	Bacilliary necrosis of Pangasianodon
CA	Competent Authority
CAA	Coastal Aquaculture Authority (India)
CDSCO	Central Drugs Standard Control Organization (India)
CEV	Carp edema virus
CIBA	Central Institute of Brackishwater Aquaculture (India)
CIFA	Central Institute of Freshwater Aquaculture (India)
CIFE	Central Institute of Fisheries Education (India)
CIFRI	Central Inland Fisheries Research Institute (India)
CIFT	Central Institute of Fisheries Technology (India)
CLSI	Clinical and Laboratory Standard Institute (India)
CIMFRI	Central Institute of Marine Fisheries Research Institute (India)
CNY	Chinese yuan
CyHv-2	Cyprinid herpesvirus-2
DA	Department of Agriculture (Philippines)
DAH	Department of Animal Health (Viet Nam)
DAHDF	Department of Animal Husbandry, Dairying and Fisheries (India)
DARE	Department of Agriculture Research and Education (India)
DCFR	Directorate of Coldwater Fisheries (India)
DCGI	Drugs Controller General of India
DGA	Directorate General of Aquaculture (Indonesia)

DGA-TIU	DGA-Terminal Implementing Unit (Indonesia)
DOF	Department of Fisheries (Malaysia)
DTQS	Department of Technology and Quality Supervision (China)
DVS	Department of Veterinary Services (Malaysia)
EHP	Hepatopancreatic microsporidiosis caused by Enterocytozoon hepatopenaei
EIC	Export Inspection Council (India)
ESC	Enteric septicaemia of catfish
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAO-FIRA	FAO Fisheries and Aquaculture Department
FAO-RAP	FAO Regional Office for Asia and the Pacific
FDA-DOH	Food and Drug Administration of the Department of Health (Philippines)
FHO	Fish health officer (Philippines)
FSSAI	Food Safety and Standards Authority of India
GAP	Good aquaculture practices
GAP-FF	GAP for fisheries farming (Singapore)
GAP-AMR	Global Action Plan on Antimicrobial Resistance
GAqP	Good aquaculture practices (Philippines)
GVA	Gross value added
HACCP	Hazard analysis and critical control point
HP	Hepatopancreas
HGT	Horizontal gene transfer
IC	International consultant
ICAR	Indian Council of Agricultural Research
ICAR-CIBA	ICAR-Central Institute of Brackishwater Aquaculture
ICAR-CIFE	ICAR-Central Institute for Fisheries Education
ICAR-CIFRI	ICAR-Central Inland Fisheries Research Institute
ICAR-CIFT	ICAR-Central Institute of Fisheries Technology
ICAR-CMFRI	ICAR-Central Marine Fisheries Research Institute
ICAR-NBFGR	ICAR-National Bureau of Fish Genetic Resources
IHHNV	Infectious hypodermal and haematopoietic necrosis virus
IMNV	Infectious myonecrosis virus
IMTA	Integrated multi-trophic aquaculture
INFAAR	Indian Network for Fishery and Animal Antimicrobial Resistance (India)
MADA	Malaysian Aquaculture Development Association

MARA	Ministry of Agriculture and Rural Affairs (China)
MARD	Ministry of Agriculture and Rural Development (Viet Nam)
MAS	Motile aeromonads septicaemia
MBV	Monodon baculovirus
MIC	Minimum inhibitory concentration
MMAF	Ministry of Marine Affairs and Fisheries (Indonesia)
MOA	Ministry of Agriculture (China)
MOAFW	Ministry of Agriculture and Farmer's Welfare (India)
MoH	Ministry of Health (Viet Nam)
MPEDA	Marine Products Export Development Authority (India)
MRL	Maximum residue limit
MyAP-AMR	Malaysian National Action Plan on Antimicrobial Resistance
MyGAP	Malaysian Good Aquaculture Practices
NACA	Network of Aquaculture Centres in Asia-Pacific
NAFIQAD	National Agro-forestry and Fishery Quality Assurance Department (Viet Nam)
NAP-AMR	National Action Plan on Antimicrobial Resistance (India)
NARC	National Antimicrobial Resistance Committee (Malaysia)
NBFGR	National Bureau of Fish Genetic Resources (India)
NFAP	National Fisheries Action Plan (India)
NFDB	National Fisheries Development Board (India)
NFTEC	National Fisheries Technology Extension Center (China)
NPCB	National Pharmaceutical Control Bureau (Malaysia)
NRCP	National Residue Control Plan (India)
OIE	World Organisation for Animal Health
OIE-RRAP	OIE Regional Representation for Asia and the Pacific
OTC	Oxytetracycline
PCR	Polymerase chain reaction
PL	Postlarvae (shrimp)
QC	Quality control
RDA	Redundancy analysis
SAP	Singapore Aquaculture Plan
SPF	Specific pathogen free
SOFIA	State of Fisheries and Aquaculture (FAO)
SOP	Standard operating procedures
TE	Tetracycline

TiLV	Tilapia lake virus
USAID	United States Agency for International Development
VietGAP	Vietnam Good Aquaculture Practices
VMP	Veterinary medical products
VNN	Viral nervous necrosis
VNNV	Viral nervous necrosis virus
WHA	World Health Assembly
WHO	World Health Organization
WSP	White spot disease
WSSV	White spot syndrome virus
WTD	White tail disease
WTO-SPS	World Trade Organization Sanitary and Phytosanitary Measures

Executive summary

The Asia-Pacific region contributes over 90 percent of the world's aquaculture production. Aquaculture production has intensified in the region but this has resulted in increased disease among cultured species. Increasing transboundary movement of aquatic animals related to seed supply and trade has further exacerbated the problem. Antimicrobials are commonly used drugs to prevent and control common aquatic animal diseases in aquaculture. Although control over the use of antimicrobials has strengthened over the past decade – mainly due to increasingly stringent safety standards for exported aquatic food – antimicrobials are still commonly used in aquaculture in the region. The control over the production and use of antimicrobials for aquaculture is far from adequate and effective in many Asian countries although some regulatory frameworks are already in place. Imprudent and poorly controlled use of antimicrobials in aquaculture can contribute significantly to the risk of antimicrobial resistance (AMR) owing to the nature of aquaculture environments and the ways in which cultured animal diseases are managed.

Due to population expansion and anticipated economy recovery and growth, the demand for food fish is expected to increase significantly in the coming decades. It is projected that fish consumption will increase by 31 million tonnes in the next decade to reach 178 million tonnes in 2025 (FAO, 2016). To meet the increasing demand for food fish globally, it is vital to maintain the sustainable growth of aquaculture in Asia. The trend of aquaculture intensification is very likely to continue in general despite limited national resources, particularly water and land, and increasing competition among different users. Effective control of infectious diseases of cultured aquatic animals will be a key factor for productivity and efficiency in aquaculture.

AMR has recently become a hot issue globally in the contexts of human and environmental health. Considering the scale of antimicrobial use (AMU) in Asian aquaculture and desire for sustainable growth of the sector, actions to address AMR risk related to aquaculture are urgently needed. Addressing AMR risks in aquaculture has been included as an integral component of FAO's One Health initiative being implemented in the Asia-Pacific region.

Organizing a regional consultation is an appropriate entry point for assessing the use of antimicrobials in Asian aquaculture and their risks in contributing to AMR; it is also an opportunity to identify desirable interventions to effectively tackle the issue and long-term strategy to minimize AMR risks related to aquaculture in the region.

This regional consultation was jointly prepared and convened by FAO and NACA in cooperation with the FAO Regular Programme Support team. It was considered to be a major activity of FAO's Regional Initiative on Blue Growth in Asia-Pacific. As preliminary preparation, eight Asian countries were jointly selected by FAO and NACA to conduct country assessment of AMU in aquaculture, its regulation and status for addressing AMR risk associated with aquaculture. The selected countries covered different levels of aquaculture development and governance in the region. An international consultant and

national experts (nominated by relevant government authorities) were recruited to support and conduct the country assessment studies and the regional synthesis as well as to provide technical input to the regional consultation.

The regional consultation was held in Bangkok, Thailand from 4 to 6 September 2018. The consultation was attended by the international consultant, national experts and representatives from 19 countries in the Asia-Pacific region (Australia, Bangladesh, Cambodia, China, Hong Kong SAR of China, India, Indonesia, Japan, Lao PDR, Malaysia, Myanmar, Nepal, Pakistan, the Philippines, Republic of Korea, Singapore, Sri Lanka, Thailand and Viet Nam); representatives from regional and international organizations (FAO-RAP, OIE-RRAP, NACA, WorldFish), the donor agency (USAID) and the academe (Chulalongkorn University) also participated.

During the consultation, national experts presented the country assessment studies; these covered a broad spectrum of aspects related to AMU and AMR risk in aquaculture and the countries' efforts to regulate AMU in aquaculture and address the risk of AMR associated with aquaculture. The international consultant presented the regional synthesis based on the country assessment studies, a literature review and his personal expertise. The consultation also included other technical presentations relevant to AMU and AMR in aquaculture.

Two working group sessions were convened for further identification of major gaps and issues regarding AMU and AMR in aquaculture in the region; measures for mitigating the risk to human and environmental health and sustainability of the aquaculture sector were also addressed. Recommendations for appropriate strategies and actions in these contexts were provided. The priority strategies included:

- Strengthening AMU/AMR regulations and their enforcement at national and local levels;
- Increasing AMU/AMR awareness among all stakeholders and the public;
- Establishing an AMU/AMR surveillance system and mechanism as well as developing the required capacity at national levels;
- Supporting development and use of alternatives to antimicrobials to enable farmers to effectively cope with aquatic animal diseases;
- Strengthening farm-level capacity for good aquatic animal health management, including good farming management practices to minimize the use of antimicrobials; and
- Strengthening research to bridge knowledge gaps.

Under each strategic area, the consultation recommended a full range of specific actions needed for better governance of AMU in aquaculture and mitigation of AMR risk associated with aquaculture for human and environmental health and sustainable development of the aquaculture sector in the region.

Background

Over 90 percent of global aquaculture production is contributed by Asia; intensification is a major contributor to the fast growth of the aquaculture industry. Aquaculture intensification, however, has resulted in rising disease problems among cultured animals. Increasing transboundary movement of aquatic animals related to seed supply and trade has further exacerbated the problem. Antimicrobials are the most commonly used drugs to prevent and control common aquatic animal diseases in aquaculture. Although control over the use of antimicrobials has been strengthened over the past decade, mainly for trade-related purposes, they are still commonly used in aquaculture in the region. The control over the production and use of antimicrobials for aquaculture is far from adequate and effective in many Asian countries although some regulatory frameworks are already in place. Imprudent and poorly controlled use of antimicrobials in aquaculture can contribute significantly to AMR risk due to the nature of the aquaculture environment and the ways in which cultured animal diseases are managed.

Due to population expansion and anticipated economy recovery and growth, it is expected that the demand for food fish will increase significantly in the coming decades. It is projected that global fish consumption will increase by 31 million tonnes in the next decade to reach 178 million tonnes in 2025 (FAO, 2016). To meet the increasing demand for food fish globally, it is vital to maintain the sustainable growth of aquaculture in Asia. The trend of aquaculture intensification is very likely to continue despite limited national resources, particularly water and land, and increasing competition among different users. Effective control of infectious diseases of cultured aquatic animals will be a key factor for productivity and efficiency in aquaculture.

Ensuring the availability and use of effective antimicrobial drugs in aquatic animals is essential for their health and productivity. This contributes to food security, food safety and animal welfare, and in turn, to the protection of livelihoods and the sustainability of aquaculture and fisheries. However, it is also now globally recognized that misuse and overuse of these substances contribute to the emergence and spread of AMR. Because of the considerable impacts on the health of humans, animals and plants, solutions for addressing this global issue need to be found.

Considering the scale of use of antimicrobials in Asian aquaculture and the need for sustainable growth of the sector, actions to address the AMR risk are urgently needed. Moreover, the lack of systematic and regular collection of optimal information on AMR in livestock and aquaculture is perhaps one of the most critical gaps relevant to AMR mitigation in agriculture. Organizing a regional consultation is an appropriate entry point to assess the use of antimicrobials in Asian aquaculture and their risks in contributing to AMR; it is also an opportunity to identify desirable interventions to address the issue and long-term strategy to minimize AMR risk related to Asian aquaculture.

In this context, FAO supported NACA to carry out an assessment on AMU, the risk of AMR associated with aquaculture and efforts made by member countries to mitigate risks. This will lead to recommendations on strategies and actions for effectively addressing AMR aquaculture risk as an integral component of FAO's One Health initiative. To achieve this objective, assessment studies on the status of AMU in aquaculture as well as regulation and governance of the use of antimicrobials were conducted in selected Asian countries, followed by a regional synthesis study. The regional consultation was then conducted to share the country case studies and further identify major issues, gaps and constraints in minimizing AMR risks related to aquaculture. Strategies and actions for effectively addressing AMR risk associated with aquaculture were recommended.

Regional consultation

Purpose of the regional consultation

The regional consultation focused on the identification of major issues, gaps and constraints in minimizing risks associated with AMR in aquaculture, based on a well-designed country assessment of the status of AMU and AMR in eight selected countries in the region (China, India, Indonesia, Malaysia, the Philippines, Singapore, Thailand and Viet Nam). It also aimed to provide strategies on addressing issues and gaps, raising awareness on AMU/AMR, promoting responsible and prudent AMU in aquaculture for human and environmental health and fostering more sustainable development of aquaculture in the region.

Expected outputs

Expected outputs from the consultation were:

- A regional assessment on the use of antimicrobials in Asian aquaculture, its governance and related AMR risks (major issues, gaps and constraints in minimizing AMR risks related to aquaculture) through well-designed country studies (eight selected countries in Asia);
- Shared knowledge and raised awareness among different stakeholders on the need to address AMR risks related to aquaculture in Asia;
- Recommended strategy and actions for effectively addressing AMR risks related to antimicrobial use in Asian aquaculture; and
- A draft document for a joint FAO-NACA publication on the regional consultation.

Country assessment study and regional synthesis

To prepare for the regional consultation, an assessment study on the use of antimicrobials in aquaculture, their regulation and efforts to address AMR aquaculture risk was planned for eight Asia countries selected by FAO and NACA. Selection of the countries for the case studies considered the level of aquaculture development and geographic coverage.

Relevant government authorities were approached for nomination of national experts to lead the country assessment study. An international expert was invited to technically support the national experts in conducting the country case studies and to prepare a regional synthesis report based on the country assessment report. The international expert was also expected to provide the latest knowledge and information on monitoring and surveillance of AMR associated with aquaculture.

To provide technical expertise in the above contexts, NACA in consultation with FAO recruited an international consultant.

Guidelines and a report template for the country assessment study were developed by the international consultant with the assistance of FAO and NACA officers. The guidelines and template were provided to the nationally nominated experts for conducting the country case studies.

Country teams completed the country assessment study reports, which were reviewed by the international consultant and NACA. The country study reports were then revised based on the review's feedback before the regional consultation. Meanwhile, the regional synthesis report was prepared by the international expert based on the country case studies and literature review.

Consultation arrangement

The regional consultation was held at the Amari Watergate Hotel, Bangkok, Thailand from 4 to 6 September 2018. The consultation was attended by the international consultant, national experts and representatives from 19 countries in the Asia-Pacific region (Australia, Bangladesh, Cambodia, Hong Kong Special Administrative Region of China, India, Indonesia, Japan, Lao PDR, Malaysia, Myanmar, Nepal, Pakistan, People's Republic of China, Philippines, Republic of Korea, Singapore, Sri Lanka, Thailand and Viet Nam), representatives from regional and international organizations (FAO-RAP, OIE-RRAP, NACA, WorldFish), the United States Agency for International Development (USAID, the donor agency) and the academe (Chulalongkorn University in Thailand).

The consultation had three major modalities:

- **Session I:** Plenary session for expert presentations on the status and importance of antimicrobial use and antimicrobial resistance in aquaculture and the risk it poses in the aquaculture industry and food safety.
- **Session II:** Plenary session for presentations on country assessment reports.
- **Session III:** Working group session for the identification of issues and gaps as well as the development of a regional strategy and action plans to promote responsible pro duction and use of feed and feed ingredients in aquaculture for sustainable growth of the sector.

Opening session

Dr Eduardo M. Leaño, Coordinator of the Aquatic Animal Health Programme of NACA, facilitated the opening session. Welcome remarks were provided by Ms Xiangjun Yao, Regional Programme Leader for FAO-RAP, who highlighted the importance of the AMR issue in aquaculture as part of the FAO National Action Plan on AMR and the tripartite One Health initiative. Welcome messages were also given by Dr Daniel Schar, Senior Regional Emerging Infectious Diseases Advisor for USAID and Dr Chumnarn Pongsri, Deputy Director-General of the Thai Department of Fisheries. Dr Cherdsak Virapat, Director-General of NACA, delivered the opening remarks and officially opened the consultation. An overview of the consultation was presented by Mr Miao Weimin (FAO-RAP, Bangkok) covering the background, objectives, process and expected outputs.

Plenary presentations

Status of AMU and AMR in the aquaculture sector of the Asia-Pacific region

Professor Li Aihua presented updates on the status of AMU and AMR in aquaculture in the region, citing some important activities and published information in some aquaculture-producing countries. The huge scale of aquaculture production, variety of cultured species and diverse aquaculture modalities create great difficulties for surveillance of AMU/AMR and the management of antimicrobials in aquaculture. In summary, weak governance and poor enforcement of policies and legislations have led to slow action on AMR in some countries of the region. Surveillance efforts on AMU/AMR in aquaculture are fragmented and heterogeneous. No systematic surveillance paradigm has been conducted in most countries. Antibiotic abuse/misuse is an issue that needs to be addressed, but the awareness of farmers on AMU and AMR issues is still limited. The results from food surveillance are rarely released publicly by regulators because they are considered commercially sensitive. Antibiotics can be purchased easily without veterinary prescriptions and their use is unsupervised. Laboratory testing to survey or monitor AMR is inadequate in some countries.

Competent authorities should pay more attention to the AMR issue, create additional budgets and develop comprehensive and practical AMR control strategies. Prevention of bacterial diseases in aquatic animals (via good aquaculture practices [GAPs]) is the key step to minimize AMU and mitigate AMR. Effective vaccines and other alternative treatments should be pursued, while measures to eliminate resistant bacteria or resistance genes in aquaculture species should be developed if possible.

The abuse of antibiotics in aquaculture must be stopped. Drugs that are critical for human medicine, such as quinolones and cephalosporins, should be ruled out from the list of approved antibiotics for aquaculture. Strategies must be developed to contain and minimize the development of AMR by implementing the following measures: increased awareness, governance-strengthening, GAPs (including biosecurity), AMU/AMR/antibiotic residue surveillance, research, innovation and One Health initiative engagement. These measures can help to achieve the development of AMR, antibiotic-resistant bacteria and antimicrobial resistance gene (ARG) transmission.

AMR surveillance initiatives in aquaculture in Asia

On behalf of Dr Melba Reantaso (FIRA, FAO Headquarters, Rome, Italy), Mr Miao Weimin provided information on: 1) the outcomes of the recently concluded project FMM/RAS/298/MUL 'Strengthening Capacities, Policies and National Action Plans on Prudent and Responsible Use of Antimicrobials in Fisheries' focusing on AMU and AMR surveillance; 2) FAO documentation on AMR in aquaculture and ongoing FAO initiatives/activities/partnerships (global level) on AMR. For the first activity, progress made by participating countries on AMR surveillance was highlighted. For Malaysia, AMR surveillance was conducted for two target bacterial species (Escherichia coli and Vibrio parahaemolyticus) in catfish, tilapia, green mussels, clams and shrimps. The Philippines undertook AMU/AMR surveillance on tilapia (Streptococcus agalactiae and S. iniae), milkfish and shrimps (V. parahaemolyticus), while Viet Nam focused on tilapia (Streptococcus and Aeromonas spp.). The results are still being reviewed to determine:

- Whether the guidance provided was appropriate, easily understood and implemented well;
- The constraints involved;
- Improvement of the guidance provided;
- How to detail stepwise implementation; and
- The type of capacity development needed by participating countries.

Regional overview on current laws and regulations relevant to AMU and AMR

Professor Li gave a general review of existing laws, regulations and policies being implemented in Asia-Pacific countries relating to AMU and AMR in aquaculture. In general, most countries in the Asia-Pacific region have implemented sound legal requirements that establish a framework for all aspects of aquaculture drugs. The registration, production, marketing, use of antimicrobial agents, antibiotic resistance surveillance and monitoring, the establishment of maximum residue limits (MRL), and monitoring of antibiotic residues in aquatic animal species are controlled by laws, regulations and policies, which vary significantly in different countries. The roles of legislation are:

- Turning policy objectives into clear obligations and making them sustainable;
- Clarifying roles and responsibilities of governments and stakeholders;
- Setting up mechanisms for coordination;
- Introducing regulatory mechanisms (licences, permits);
- Regulating inspections; and
- Penalizing violations.

The gaps identified in most participating countries included inadequate specific regulations on the management of antibiotic use in aquaculture and apathy about the environmental spread of AMR originating from aquaculture. Most countries in this region also lack sufficient restrictions on the sale of aquatic antibiotics resulting in free access to antimicrobial agents via multiple pathways for farmers. Surveillance programmes in many countries to monitor antibiotic residues in aquatic products are implemented but there are no corresponding legal provisions for punishment when noncompliance is detected. At the legislative level, there is a lack of attention to the discharge and treatment of aquaculture wastewater contaminated with antimicrobial drugs. Lastly, each country has a list of approved and banned antimicrobials for aquaculture but the differences in the variety of antimicrobial agents allowed among countries in the region are significant and lack unified approved and banned lists antimicrobials.

AMU in aquaculture: important bacterial diseases of aquatic animals

Dr Eduardo Leaño elaborated on the importance of aquatic animal diseases as a cause of serious economic and production losses in the aquaculture industry in the region. Bacterial diseases, specifically, have been the main reason for the increased use of AMUs in aquaculture in the past decades. The development of AMR through continuous and irresponsible antimicrobial use and sometimes abuse has resulted in several antimicrobials becoming ineffective in aquaculture. Significant bacterial diseases among aquatic animals include:

- Vibriosis in marine fish;
- Motile Aeromonas septicaemia in freshwater fish;
- Edwardsiellosis (enteric septicaemia) of catfish; and
- Acute hepatopancreatic necrosis disease of marine shrimps.

Country presentations

Eight countries in the Asia-Pacific region were selected to undertake national assessment on the status of AMU and AMR in aquaculture. The country assessment studies were based on available data, best knowledge of the expert on current/past activities on AMU and AMR (including surveillance) as well as information collection by the expert. The assessments included (but were not limited to):

- A short background on the aquaculture industry (major species cultured, culture systems, production, etc.) and major disease issues;
- Agencies responsible for regulation and monitoring of AMU and AMR in aquaculture;
- Use of antimicrobials in aquaculture (past and present), types of antimicrobials, target animals and farming systems, methodology of use, estimated quantity (range by species and farming systems) and potential AMR risks related to aquaculture (human, animal and environmental);
- List of approved and banned antimicrobials in aquaculture;
- National action plan/strategy on AMU and AMR;
- Other national regulations pertaining to the supply, sale and use of antimicrobials;
- Issues, gaps and constraints in the implementation of regulations and plans/strategies for AMU and AMR;
- Monitoring and surveillance of AMU and AMR; and
- Strategy and actions in addressing AMR risks in aquaculture, e.g. alternatives to antimicrobials; better aquatic animal health management practices; biosecurity control and so forth.

The complete national assessment reports are provided in Annex 5.

Other presentations

Representatives from Japan (Dr Ikuo Hirono) and China (Dr Zhang Rui-Quan and Professor Jiang Lan) spoke about AMR in aquaculture in their respective countries. Dr Hirono presented 'Antimicrobial resistant bacteria in aquaculture (Japan)'; topics included multidrug-resistant bacterial infections, approved aquatic medicines in Japan, rules and regulations of the Japanese Government on the administration of aquatic medicines, and activities of the Japanese Veterinary Antimicrobial Resistance Monitoring System. Dr Zhang described the 'Survey on antimicrobial resistance in aquaculture, Guangdong Province, China', which covered aspects of disease control in aquaculture, AMR surveys and AMR mechanisms in aquaculture.

Working group sessions

Two working group sessions were conducted for different tasks. The participants were divided into three groups for each working group session, which had the same assignment.

Working Group Session One: Identification of major issues and gaps in management and regulations on the use of antimicrobials in aquaculture and tackling the issue at national levels.

Working Group Session Two: Recommendations of strategies and specific actions for mitigating AMR risks in aquaculture in the region.

Outputs from the working group sessions

Major issues and gaps

The Working Group Session identified the following constraints for effectively regulating AMU and mitigating the regional risk of AMR in aquaculture to human and environmental health as well as the sustainability of the sector:

- Inadequate national regulations on AMU and AMR, especially at the farm level (lack of regulated AMU and restricted distribution of antimicrobials in aquaculture);
- Lack of well-trained personnel to provide veterinary prescription for use of antibiotics and to advise farmers (there are many smallholders) on the proper use of antibiotics;
- Weak farm-level capacity for improved animal health management to minimize the use of antimicrobials;
- Lack of public awareness programmes on AMU and AMR;
- Lack of alternatives to banned antimicrobials;
- Inadequate emphasis on good farming management practices, which are vitally important for effective prevention of diseases in aquaculture;
- Limited AMR surveillance in aquaculture due to inadequate financial and human capacity;
- Lack of harmonized methodology for AMU and AMR surveillance as well as AMU evaluation;
- A weak scientific knowledge base on antimicrobial pathways in aquaculture and related mechanisms;

- Lack of collaboration with other sectors that are using antimicrobials (livestock, crops) especially on waste management and disposal of antimicrobials, which impact on aquatic environments and animal husbandry; and
- Lack of coordination among stakeholders along the aquaculture supply chain (feed mills, postharvesting actors, processors, etc.) in addressing the risks of AMU and AMR to food safety.

Recommendations from the consultation

To effectively address regional AMR risks and AMU/AMR management in aquaculture, the following key priority areas were identified by the consultation:

- AMU/AMR regulations and implementation;
- AMU/AMR awareness;
- AMR surveillance;
- Alternatives to antimicrobials;
- Farm-level capacity for good aquatic animal health management to minimize the use of antimicrobials; and
- Bridging knowledge gaps, especially on understanding AMU and AMR in aquaculture.

Strengthening AMU/AMR regulations and their enforcement

Some countries in the region have existing regulations on the use of antimicrobials in aquaculture, but their appropriateness, especially at the farm level, needs to be addressed for better management of AMU. Most regulations pertaining to the use of antimicrobials do not properly address proper distribution and selling of antimicrobials, implementation of veterinary prescriptions prior to use of antimicrobials, and proper use and administration of antimicrobials (including withdrawal periods). Some of the recommendations to address these issues were:

- Proper enforcement and implementation of the regulations (if in place) by the Competent Authority (CA) in different sectors involved in aquaculture production, including distributors/suppliers of antimicrobials, feed manufacturers and the farmers;
- The CA should provide farmers with a list of approved and banned antimicrobials and guidelines should also be developed for the proper use of antimicrobials at the farm level;
- There is a need to include appropriate susceptibility tests in the guidelines to determine the correct antimicrobial to use for specific diseases; and
- Prescription of veterinary drugs for aquaculture use is mostly nonexistent in the region; a prescription policy should be developed by the CA in collaboration with relevant government institutions, which can be implemented by accredited/certified veterinarians and/or aquatic animal health specialists who can undertake proper diagnosis of the disease.

Enhancement of AMU/AMR awareness

Aquaculture farmers lack awareness of AMU and AMR in most countries in the region. In some countries, even extension officers do not have adequate knowledge of AMU and AMR. There is also lack of collaboration with other sectors that are using antimicrobials (e.g. livestock and crops) and lack of involvement of other sectors in aquaculture production, including feed mills and processing plants. The following actions were recommended:

- A targeted level of awareness campaign programme;
- Training programmes under the One Health initiative involving human resource and livestock sectors should be undertaken, as the use of antimicrobials among these sectors is usually interrelated;
- Training of trainers for extension officers on AMU/AMR as well as on GAPs, as they are instrumental in servicing local fish farmers; and
- In terms of collaboration with other production sectors and among stakeholders involved in aquaculture production, there is a need to assess the use of antimicrobials in some interactive points (e.g. use of livestock manure for pond fertilization; disposal of fish waste products after processing that might contain antimicrobial residues) to perform countermeasures prior to utilization or disposal of these residues.

Establishing an AMU/AMR surveillance system and mechanism

Generally, there is a great variation in undertaking AMU/AMR surveillance activities for aquaculture in the region. Some countries concentrate more on AMU surveillance than AMR, while others are still at the planning stage for AMR surveillance. Few countries are currently undertaking active AMR surveillance for selected bacterial pathogens and cultured species. The lack of a common or harmonized methodology for AMR surveillance was the key problem/issue identified. Specifically, the lack of quality control (QC) strains for important bacterial pathogens in aquaculture and no standard for the selection of bacterial strains (priority micro-organisms to be tested for AMR) were considered the main issues to be resolved. Clinical breakpoints and a standard list of antibiotics to be tested are also absent and should be subjects for regional comparison. Human capacity for undertaking AMR surveillance and sensitivity testing is limited in most countries in the region.

Recommended actions:

- Identification of target bacterial pathogens and QC strains for each identified pathogen as well as target cultured aquatic animals (including types of sample, number of samples, etc.);
- Development of standardized (harmonized) operating procedures (SOPs) for AMR surveillance of aquatic animal pathogens as well as a standardized national list of antibiotics for testing (which should be comparable at the regional level);
- Suggested SOPs for AMR surveillance should be antimicrobial sensitivity testing (AST) as an initial procedure, followed by minimum inhibitory concentration (MIC) and ARG detection;

- AMR surveillance should also follow the One Health initiative by aligning analysis and results with human data (e.g. for E. coli, Staphylococcus and Salmonella); and
- Human capacity development through skills training and development should be provided, while sharing of resources and expertise on AMR should be promoted.

Support development and use of alternatives to antimicrobials

Currently, there is limited information on alternatives to antimicrobials, especially at the farm level. One of the most promoted alternatives is the use of vaccine; however, acceptance by farmers is very limited due to the high cost of treatment and limited availability in the market. Thus, the following actions were recommended:

- Preventive measures should be promoted to reduce the incidence of diseases through GAPs and biosecurity measures;
- Plant-based alternatives can be explored as potential replacement to synthetic antimicrobials;
- Quorum sensing technology for disease inhibition, other biological agents (bacterio phages, probiotics) and immunostimulants (chitosan, ß-glucan) that have proven effective for disease prevention should be promoted for use on aquaculture farms; and
- Development of low-cost vaccines should be continued for specific diseases, as they have proved to be highly effective for disease prevention.

Strengthening farm-level capacity for good aquatic animal health management to minimize the use of antimicrobials

Data and information on AMU and AMR in the aquaculture sector are limited, especially for determining the actual dosage of antimicrobials due to the complexity of the industry; there is no record-keeping of total amounts of antimicrobials used and no fixed duration of antimicrobial usage during treatment of a disease and/or when used for prophylactic treatment. These constraints are coupled with the lack of trained officials, policy-makers and/or extension workers who can advise farmers on the prudent use of antimicrobials as explained earlier. To minimize the use of antimicrobials at the farm level, the following recommendations were made:

- Promote farmers' education and training on improved or better farm management practices including proper stocking densities, feeding management and waste management;
- Promote farm-level biosecurity and alternative measures in the overall better prevention and management of disease outbreaks; and
- Promote proper record-keeping during culture operations, including usage of chemicals and drugs, water quality parameters and feeding, among other factors.

Support research to bridge the knowledge gaps

The limited data available on AMU and AMR in aquaculture do not imply that there are no projects and studies being undertaken on these issues. However, many projects and activities that have been implemented overlap in terms of scope and coverage, leaving significant gaps in completely understanding the importance and impact of prudent AMU and development of AMR. To fill such gaps, the following research topics were recommended:

- Research on AMU correlating with AMR cross-resistance;
- Data analysis – direction of transmission of antimicrobial resistance (at the gene level);
- Metabolism and persistence of antibiotics in the ecosystem (soils and water);
- Research on transferable drug resistance (fish pathogens to human pathogens);
- Research on possible co-resistance;
- Research on withdrawal periods (species- and ecosystem-wise) – pharmacokinetics and pharmacodynamics; and
- Methodologies to estimate losses due to AMR in aquaculture.

Status of AMU and AMR in the aquaculture sector of the Asia-Pacific region

Aihua Li
Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan,
P.R. China, 430072

Introduction

The aquaculture industry has grown dramatically and plays an important role in the world's food supply chain. The consumption of fish originating from aquaculture and the number of species under intensive culture have increased during the last few years. Global production of various aquatic species (finfish, crustaceans and molluscs) has also grown remarkably. Aquaculture, especially in the Asia-Pacific region, has developed rapidly over the past decades. Historically, the Asia-Pacific region has dominated global aquaculture production in both quantity and value and amounted to 88 percent and 79 percent of the global total aquatic animal production and value, respectively, in 2014. Production in the Asia-Pacific region is expected to increase continuously to meet growing global and regional demand for fish in the following decades.

This widespread growth of aquaculture has been accompanied by increased use of various chemicals, including antimicrobials. Almost all of the antimicrobials used in animal husbandry are structurally related to those used in human medicine, thereby promoting co-resistance and cross-resistance (Santos and Ramos, 2018). Six common classes of antibiotics (aminoglycosides, macrolides, penicillin, quinolones, sulphonamides and tetracyclines) included in the World Health Organization (WHO) list of critically important antimicrobials for human medicine are also commonly used in aquaculture.

Key facts about AMU and AMR

AMU has five major purposes in aquaculture: therapeutic, metaphylactic, prophylactic, growth promotion and control of cyanobacterial bloom (such as erythromycin). Routes for AMR genes or entry of resistant bacteria in the culture system include selection and mutation caused by antimicrobials that were directly applied to the system and present in sediment, water sources, seed, feed (fishmeal, frozen fish, trash fish and antimicrobials artificially added), probiotics and livestock manure. Humans can be exposed to AMR bacteria through many pathways, such as food consumption, transmission of AMR along the food chain, drinking water, and direct environmental and medical contact. Understanding these facts helps in developing strategies to curb the prevalence of drug resistance and drug-resistant bacteria.

Excessive use of antimicrobials in aquaculture can negatively affect aquatic animals, human health and the aquatic environment. Aquaculture uses hundreds of tonnes of antimicrobials annually to prevent and treat bacterial infections. The most obvious detrimental effect of extensive use of antimicrobials in aquaculture is the selection of aquatic pathogens that are resistant to multiple antimicrobials, which in turn produce difficult or impossible to treat epizootics (Lin, 1989; Kautsky et al., 2000). Antimicrobial residues in fish meat can potentially alter normal human intestinal flora, select antimicrobial-resistant bacteria and aid infection with human pathogens. Antimicrobials present in fish tissues and in the environment can fuel horizontal gene transfer (HGT) and mutagenesis. Many bacteria possess multiple antibiotic-resistant genes. Hence, the use of any of these antibiotics helps to maintain them in the population.

Antibiotics entering the water environment may constitute a more serious hazard than antibiotic residues in aquatic products in terms of AMR development. Given that fish do not effectively metabolize antibiotics, the active substance largely passes into the environment in the faeces, and approximately 70 percent to 80 percent of the antibiotics applied in aquaculture are dispersed into water systems. These substances remain for months at sufficiently high concentrations and thus exert selective effects on aquatic bacterial diversity in these environments. Introducing large amounts of antimicrobials into the aquatic environment rapidly leads to the emergence of multiple-resistant bacteria because ARGs enhance fitness for growth in sediments containing antimicrobials. Aquatic environments associated with aquaculture can serve both as reservoirs of ARGs and antimicrobial-resistant bacteria and as facilitators for HGT. Many aquatic bacteria harbour various mobile genetic elements, such as plasmids, integrons and transposons that can easily move, recombine and mobilize. These elements promote the emergence of new mobile combinations of ARGs, conferring to bacteria the capacity to rapidly adapt to new environments where antimicrobials are present. Continuous long-term use of antibiotics mainly influences the increased transfer of ARG among micro-organisms (Szczepanowski et al., 2009; Cheng et al., 2012; Moura et al., 2012). The frequency of detection of AMR genes in aquatic bacteria can be correlated with the amounts of antimicrobials used (Shah et al., 2012).

Once acquired, ARGs persist in the environment for a long period, even after exposure has been terminated. AMR is acquired rapidly, but the reverse process is notably slow or non-existent. Exposure to low levels of antibiotics increases the MIC to higher levels than the cells were exposed to (van der Horst et al., 2011). Bacteria from the aquatic environment share genetically-related resistance elements with aquatic animals. Thus, human pathogens can link with the resistomes of aquatic bacteria and support the establishment of the link among the AMU in animals, the emergence of resistant bacterial strains and the transfer of resistance to human pathogens. Many AMR determinants are found in fish pathogens and other aquatic bacteria and are shared with human pathogens (Santos and Ramos, 2018). Conversely, AMR determinants in fish pathogens can also be acquired from environmental antimicrobial-resistant bacteria that have been selected by residual antimicrobials in water and sediments (Su et al., 2015; Singer et al., 2016).

Given that some fish pathogenic bacteria are zoonotic bacteria, selecting the resistance in bacteria associated with human disease is of major concern in aquaculture. Although many aquatic pathogens exhibit a narrow host range, significant risk to public health can develop through evolutionary processes, in which genes, including AMR and virulence genes, can be transferred among different species and genera of bacteria.

Status of AMU in the aquaculture sector of the Asia-Pacific region

Data on the quantities of antimicrobial agents used in aquaculture are not available in most countries, but the amount of antimicrobials used in aquaculture in most developed countries is limited. The lack or insufficiency of registered antimicrobials may contribute to the illegal use or off-label use of antimicrobials occurring in some countries. The amount of antimicrobials used in aquaculture is difficult to assess because of the large size and geographical extent of the industry, the various modalities employed (i.e. extensive, integrated and intensive), and the 200-plus species of aquatic animals involved. Collecting information about AMU in aquaculture is further complicated by a wide range of proprietorships, especially due to the large number of family units and small businesses.

The status of AMU and AMR of major aquaculture countries in the region is briefly described below based on the information currently available online.

China and East Asia: Few rigorous surveys on AMU in the aquaculture sector in China have been conducted. A large-scale investigation by Liu et al. (2017) showed that 20 antibiotics, including 13 authorized species, are being used in Chinese aquaculture to control disease-causing organisms, whereas 32 compounds are found in aquatic products. This indicates that aquaculture settings, including fish feed and water sources, are contaminated by various antimicrobial agents. Quinolones are the most frequently detected category in aquatic products, followed by sulphonamides and macrolides. Ciprofloxacin, norfloxacin and sulphisoxazole show the highest residual levels by specific compound. The mean concentrations of antibiotics in aquatic products are lower than the MRLs. Wen et al. (2017) investigated three counties in a typical aquaculture region of China (Hubei Province) and showed that the usage of antimicrobial agents accounted for 0.68 percent and 2.18 percent, 14.67 percent and 17.24 percent, or 1.98 percent and 6.40 percent of the total annual usage for three different counties in 2011 and 2012, respectively. Among the antimicrobials, 70 percent or more were enrofloxacin. The medicinal cost per kilogram of fish production was CNY 0.11 and CNY 0.35 for two counties investigated in 2012.

Prophylactic treatment by antimicrobials is currently rare in China and the CAs are actively advocating antibiotic reduction action in animal farming, including aquaculture. Therefore, good practices and the application of antibiotic alternatives, such as vaccines, prebiotics and probiotic micro-organisms, and herbal medicine have become increasingly popular.

There are six common classes of antibiotics (aminoglycosides, macrolides, penicillin, quinolones, sulphonamides and tetracyclines) on the WHO list of critically important antimicrobials for human medicine, but only four classes (aminoglycosides, quinolones, sulphonamides, and tetracyclines) are allowed and are commonly used in aquaculture in China.

For many years, researchers have investigated the AMR status of fish pathogenic bacteria isolated from various aquatic animals cultured in marine or freshwater in different aquaculture regions in China. These data can be found in the literature. However, these findings are fragmented and lack year-wise comparison for fixed sampling sites or areas. However, government authorities have been conducting a yearly nationwide AMR survey programme in the aquaculture sector since 2015, but the results have not been publicly released yet.

In the Republic of Korea (ROK), heavy contamination of multidrug resistant bacteria in 18 major food items, including beef, pork and fisheries, was found. The occurrence of antibiotic-resistant bacteria isolated from freshwater aquaculture effluents (catfish, trout, eel and loach) was investigated in ROK. Twenty bacterial strains were isolated and half were Aeromonas sp. Bacteria resistant to only one antimicrobial constituted 41.7 percent and multiple antibiotic-resistant bacteria constituted 58.3 percent. Disinfection of antibiotic-resistant bacteria by electron beam (E-beam) irradiation was carried out using an electron accelerator that was effective in this respect. The isolated bacteria were completely disinfected at a dose of less than 2 kGy (Lim et al., 2013).

Ornamental fish may represent a potential source of multiresistant bacteria and mobile genetic elements for the environment and for humans (Dobiasova et al., 2014). PMQR-positive isolates from imported ornamental fish have shown higher MIC levels to quinolones, multiresistance and diverse content of antibiotic resistance genes and integrons compared with isolates from carps.

Southeast Asia and South Asia: According to FAO, all classes of antimicrobials important for human medicine are used in aquaculture species in Southeast Asia. Nitrofurans, chloramphenicol and nitroimidazoles are prohibited in all Association of Southeast Asian Nations (ASEAN) countries for food-producing animals but are allowed for use on ornamental fish in some countries. In Southeast Asia, the use of antimicrobials is also normal in intensive aquaculture and integrated agriculture–aquaculture systems. Antimicrobials, including critically important antimicrobials for human use, are routinely used in 70 percent of aquaculture systems in Viet Nam and Thailand (Dang et al., 2015; Collignon et al., 2016). Approximately 26.9 percent of fish and shrimp samples bought in local markets in Viet Nam contained antimicrobial residues.

As of 2018, Viet Nam possessed 814 registered products (drugs, chemicals and vitamins), of which 12.9 percent was imported and 216 products contained antimicrobials (Van, 2017). Farmers often use 14 antibiotics to treat diseases in pangasius catfish, of which amoxicillin, doxycycline and florfenicol were the three most used antibiotics at surveyed farms in Viet Nam. Fish farms discharge wastewater directly into the rivers (63 percent) and primary canals (19 percent) (Lam et al., 2009). The quality of antimicrobial products is another problem in Viet Nam, where only 4 out of 11 products have a single antimicrobial and 2 out of 10 products have a mixture of antimicrobials containing active substances within ±10 percent of the concentration declared on the product label.

In the Philippines, surveys on AMU in aquaculture involved determination of the current range of veterinary medicines applied and assessment of the perceptions of 69 respondents (Regidor and Somga, 2017) as well as investigation into the antibiotic-resistant bioluminescent Vibrio isolates from Philippine-cultured tilapia and milkfish.

Published information about AMR related to aquaculture from Indonesia is rare. Thirty-two isolates of Vibrio parahaemolyticus isolated from cockles were tested for sensitivity to 16 antibiotics by Zulkifli et al. (2009). All isolates were found to be multiresistant (defined as resistant to at least three different antibiotics) with multiple antibiotic resistance indexes ranging from 0.31 to 0.69, indicating that the isolates originated from high-risk sources of contamination where antibiotics are often used.

A strict list of banned drugs has been issued for aquaculture in Singapore. The aquaculture industry is the largest user of antimicrobials in Singapore, with 77.5 percent of the antimicrobials sold in 2016 being used in this sector. Antimicrobials are not used for growth promotion. Certain antimicrobials, such as nitrofurans, chloramphenicol and avoparcin, are prohibited for use in feed and all food-producing livestock and aquaculture farms. Fourteen vaccines were registered for aquaculture in July 2018, including eight autogenous vaccines (conditionally registered).

In India, the government often fails to monitor compliance and enforce law so many unapproved products throng the markets. Actual data on AMU in aquaculture are not available in India, but an indirect evaluation on the usage of antibiotics in aquaculture was obtained by detecting the presence of antibiotic residues and their metabolites in aquatic animals. Active surveillance for assessment of AMR is on the agenda. No commercial vaccines are available against major diseases of finfish in India, but some candidate vaccines are under development. Several alternatives to antimicrobials, such as phage therapy, pre- or probiotics, essential oils and immunostimulants, are commercially available. These alternatives are also being used widely in the region, especially in China and Southeast Asian countries.

Oxytetracycline, fluoroquinolone, doxycycline and cephalexin are the most commonly used antibiotics in India. Fish feed manufactories may incorporate antimicrobials into their products secretly for growth promotion and disease prevention. From 2002 to 2003, various chemicals were widely used in Bangladesh shrimp farming, such as chloramphenicol, erythromycin, neomycin, oxytetracycline and prefuran (Uddin and Kader, 2006).

Antibiotic contaminations in aquaculture effluent water in Sri Lanka have been investigated (Manage, 2018). It was revealed that the concentrations of antibiotics belonging to the tetracycline group were higher than those of the other selected antibiotics. The measured erythromycin concentrations in effluents of a few aquaculture sites were low, and antibiotic groups, such as penicillin and sulphonamide, were not detected in effluent samples.

Australia and New Zealand: With small but rapidly developing industries and with rigorous regulatory control, no antibiotics have been registered for use in aquaculture, but restrictions on the availability of registered products lead to pressure in using antibiotics off-label or even illegally.

Issues and gaps

The huge scale, enormous aquaculture production and variety of cultured species in this region as well as diverse aquaculture modalities make surveying of AMU/AMR and the management of antimicrobials in aquaculture very difficult. In summary, weak governance and poor enforcement of policies and legislations have led to slow action on AMR in some countries of the region. Surveillance efforts on AMU/AMR in aquaculture are fragmented and heterogeneous. No systematic paradigm surveillance has been conducted in most countries.

Antibiotic abuse/misuse is an issue that needs to be addressed, but the awareness of farmers on AMU and AMR issues is still limited. The results from food surveillance are rarely released publicly by regulators because they are considered commercially sensitive. Antibiotics can be purchased easily without veterinary prescriptions and the use of antibiotics is unsupervised. Laboratory testing capacity to survey or monitor AMR is inadequate in some countries.

Recommendations

CAs should pay attention to AMR issues, create additional budgets and develop comprehensive and practical AMR control strategies. Prevention and control of bacterial diseases in aquatic animals (GAPs) is the key step to minimize AMU and mitigate AMR. Effective vaccines and improved systems for mass vaccination of finfish should be developed. Further studies, especially those focusing on understanding the evolution and epidemiology of resistant bacteria and resistance genes, are urgently required. Measures to eliminate resistant bacteria or resistance genes in aquaculture should be developed if possible.

The abuse of antibiotics in aquaculture must be stopped. A reduction in antibiotic use in aquaculture must become a trend. Baseline and background data for AMR in the environment are necessary. Standard technology and criteria are critical for studying

AMR in aquaculture. The category of antibiotics for aquaculture use should be minimized. Drugs that are critical for human medicine, such as quinolones and cephalosporins, should be ruled out from the list of legal antibiotics. This action may be more important than reducing the total usage of antibiotics in aquaculture in terms of mitigating the threat to humans. Harmonizing the alignment of antibiotic categories for aquaculture use among regional countries is needed in this region, otherwise efforts to control AMR will be negated.

Strategies must be developed to contain and minimize the development of AMR by implementing the following measures: increased awareness, governance strengthening, GAPs (including biosecurity), AMU/AMR/antibiotic residue surveillance, research, innovation and One Health initiative engagement. These measures can help to prevent the development of AMR, antibiotic-resistant bacteria and ARG transmission.

Conclusion

Controls on AMU and AMR in aquaculture vary widely from country to country in the Asia-Pacific region. The abuse of antibiotics in aquaculture, especially prophylaxis, must be stopped. Antibiotics must be used only to treat diagnosed bacterial diseases. Reducing antibiotic use in aquaculture must become a trend. However, solving the AMR issue in the aquaculture sector by simply relying on aquaculture itself is impossible. Concerted action of all relevant sectors in society and international and regional cooperation using the One Health initiative are required.

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Annex 1 Programme of the regional consultation

Regional Consultation and Related Study on Antimicrobial Resistance (AMR) Risk to Aquaculture in the Asia-Pacific Region

4–6 September 2018
Amari Watergate Hotel, Bangkok, Thailand

PROVISIONAL AGENDA

Time	Agenda	Resource person(s)
3 September (Monday): Arrival of participants		
Day 1 (4 September, Tuesday)		
08.00 – 08.45	Registration	Secretariat
08.45 – 09.40	Opening session • Welcome remarks • Welcome remarks • Welcome remarks • Opening remarks • Group photo	**Ms Xiangjun Yao** Regional Programme Leader FAO–RAP **Dr Daniel Schar** Senior Regional Emerging Infectious Diseases Advisor **Dr Adisorn Promthep** DG of DOF–Thailand **Dr Cherdsak Virapat** DG of NACA Secretariat
Plenary Session 1		
09.40 – 09.50	Self-introductions	Participants
09.50 – 10.10	Introduction to the regional consultation on AMR risk associated with aquaculture in the Asia-Pacific region	**Mr Miao Weimin** FAO-RAP
10.10 – 10.25	***Coffee***	
10.25 – 11.00	Status of AMU and AMR in the region	**Prof. Aihua Li** International Consultant China
11.00 – 11.30	FAO AMR initiatives in Asia	**Dr Carolyn Benigno*** FAO–RAP
11.30 – 12.00	AMR surveillance initiatives in aquaculture in Asia	**Dr Melba Reantaso (presented by Mr Miao Weimin)** FAO
12.00 – 12.30	Developing the framework of AMR surveillance in Asia	**Mary Joy Gordoncillo*** FAO–RAP

* Plenary for the AMR monitoring consultation which was held back-to-back with this consultation.

Time	Agenda	Resource person(s)
12.30 – 13.30	***Lunch***	
13.30 – 14.00	Regional overview on current laws and regulations relevant to AMU and AMR	**Prof. Aihua Li** International Consultant China
14.00 – 14.30	AMU in aquaculture: Important bacterial diseases of aquatic animals	**Dr Eduardo M. Leaño** NACA
Plenary Session 2: Country reports on national assessment on status of AMU and AMR		
14.30 – 15.00	China	**Prof. Hu Kun**
15.00 – 15.30	Indonesia	**Ms Mukti Sri Hastuti**
15.30 – 16.00	***Coffee***	
16.00 – 16.30	India	**Dr Gaurav Rathore**
16.30 – 17.00	Malaysia	**Ms Rozana Binti Johari (presented by Mr Azlan bin Md. Nor)**
17.00 – 17.30	The Philippines	**Dr Sonia Somga**
17.30 – 18.00	Singapore	**Dr Kelvin Lim**
19.00 –	Hosted dinner	
Day 2 (5 September, Wednesday)		
Plenary Session 2: Continued		
08.30 – 09.00	Thailand	**Dr Thitiporn Laoprasert (presented by Dr Pornpimol Tewpair)**
09.00 – 09.30	Viet Nam	**Dr Vo Dinh Chuong**
09.30 – 10.00	Japan	**Prof. Ikuo Hirono**
10.00 – 10.15	***Coffee***	
Plenary Session 3: Working group discussions		
10.15 – 12.30	Working group discussion 1	**Dr Aihua Li/Dr Eduardo M. Leaño**
12.30 – 13.30	Lunch	
13.30 – 15.30	Working group discussion 2	**Dr Aihua Li/Dr Eduardo M. Leaño**
15.30 – 16.00	***Coffee***	
16.00 – 17.00	Working group discussion 2 (continued)	**Dr Aihua Li/Dr Eduardo M. Leaño**
Day 3 (6 September, Thursday)		
Plenary Session 4: Working group presentations and recommendations		
08.30 – 10.00	Presentation of working group discussion	Participants
10.00 – 10.15	***Coffee***	
10.15 – 12.00	Formulation of recommendations and way forward	**Dr Aihua Li/Mr Miao Weimin**
12.00 – 13.00	***Lunch***	

Annex 2 List of participants of the regional consultation

I. National experts/country representatives
Australia
Dr Leigh S. Nind Principal Veterinary Officer Epidemiology and One Health Section, Animal Health Policy Branch Biosecurity Animal Division Department of Agriculture and Water Resources 7 London Circuit, Canberra ACT 2601 Australia
Bangladesh
Dr Md. Zillur Rahman Deputy Director (Aquaculture) Department of Fisheries Dhaka, Bangladesh
Cambodia
Mr Neang Savuthdy Vice Chief, Freshwater Aquaculture Division Department of Aquaculture Development Fisheries Administration 186 Preah Norodom Blvd, Phnom Penh Cambodia
China
Prof. Hu Kun College of Fisheries and Life Sciences Shanghai Ocean University Shanghai, P.R. China **Ms Jiang Lan** Pearl River Fisheries Research Institute Chinese Academy of Fisheries Sciences No. 1, Xingyu Road, Liwan District, Guangzhou P.R. China **Dr Zhang Ruiquan** Pearl River Fisheries Research Institute Chinese Academy of Fisheries Sciences No. 1, Xingyu Road, Liwan District, Guangzhou P.R. China

Hong Kong SAR
Dr Jim Chiu Agriculture, Fisheries and Conservation Department Hong Kong SAR **Dr Les Sims** Animal Disease Intelligence c/o Agriculture, Fisheries and Conservation Department Hong Kong SAR
Indonesia
Ms Sri Mukti Hastuti Directorate General of Aquaculture Ministry of Marine Affairs and Fisheries Jakarta, Indonesia **Mrs Siti Fatimah** Analyser of Fish Health and Environment Directorate General of Aquaculture Ministry of Marine Affairs and Fisheries Jakarta, Indonesia **Mr Darma Utama** Directorate General of Aquaculture Ministry of Marine Affairs and Fisheries Jakarta, Indonesia
India
Dr Gaurav Rathore ICAR-National Bureau of Fish Genetic Resources Lucknow, India **Dr B. Madhusudana Rao** Principal Scientist Visakhapatnam Research Center Central Institute of Fisheries Technology Ocean View Layout Pandurangapuram, Andra University P.O. Visakhapatnam – 530 003, Andra Pradesh India
Japan
Dr Ikuo Hirono Professor Tokyo University of Marine Science and Technology 4-5-7, Konan, Minato-ku Tokyo 108-8477, Japan

Dr Hiroki Yanagisawa Section Chief Fish and Fishery Products Safety Office, Animal Products Safety Division Ministry of Agriculture, Forestry and Fisheries (MAFF) 1-2-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-8950 Japan
Malaysia
Mr Azlan bin Md. Nor Head, Freshwater Aquaculture Aquaculture Development Division Department of Fisheries Putrajaya, Malaysia
Myanmar
Ms Myat Myat Htwe Assistant Director Department of Fisheries Yangon, Myanmar **Ms Aye Aye Maw** Fisheries Officer Department of Fisheries Yangon, Myanmar
Nepal
Mr Jageshwar Yadav Senior Fisheries Development Officer Fisheries Development Center, Fattepur Bara District Nepal **Mr Mahesh Chand Gupta** Senior Fisheries Development Officer Fisheries Development Center, Bhairahawa Rupandehi District Nepal
Pakistan
Dr Farooque Hassan Director (Projects) Ministry of Maritime Affairs Islamabad, Pakistan **Dr Muhammad Asif Riaz** Assistant Fisheries Development Commissioner Ministry of Maritime Affairs Islamabad, Pakistan

The Philippines
Dr Sonia Somga National Fisheries Laboratory Division Bureau of Fisheries and Aquatic Resources Arcadia Building, 860 Quezon Avenue Quezon City, the Philippines **Mr Robert Magdaug** Head Regional Fisheries Laboratory VI Fisheries Production and Support Services Division Bureau of Fisheries and Aquatic Resources Regional Office No. 6 Muelle Loney St., Iloilo City, the Philippines
Singapore
Dr Kelvin Lim Director (Surveillance & Inspection Department), Agri Establishment Regulation Group Agri-Food and Veterinary Authority of Singapore 10 Perahu Road, Singapore **Dr Jun Hui Jiang** Agri-Food and Veterinary Authority of Singapore 10 Perahu Road, Singapore
Sri Lanka
Mr P. Nimal Chandraratne Director National Aquaculture Development Authority Colombo, Sri Lanka **Mr W.C. Jayaweera** Assistant Director on Investment Promotion National Aquaculture Development Authority Colombo, Sri Lanka
Thailand
Dr Pornpimol Tewpair Fisheries Biologist Aquatic Animal Health Research and Development Division Department of Fisheries Bangkok, Thailand **Ms Chantana Kaewtapee** Fishery Biologist Coastal Aquaculture Research and Development Regional Center 5 Phuket, Thailand

Mr Chanotit Nakmanoch
Veterinarian
Aquatic Animal Health Research and Development Division
Department of Fisheries
Bangkok, Thailand

Viet Nam

Dr Vo Dinh Chuong
Department of Animal Health
Ministry of Agriculture and Rural Development
Hanoi, Viet Nam

Dr Nhu Van Can
Director, Aquaculture Department
Directorate of Fisheries
Ministry of Agriculture and Rural Development
Hanoi, Viet Nam

II. International consultant

Prof. Li Aihua
State Key Laboratory of Freshwater Ecology
and
Biotechnology Institute of Hydrobiology
Chinese Academy of Sciences
Wuhan, Hubei, P.R. China

III. International and regional organizations and donors

OIE Regional Representation for Asia and the Pacific
Dr Akinobu Kawamura
Regional Veterinary Officer
OIE Regional Representation for Asia and the Pacific
Food Science Building 5F, The University of Tokyo
1-1-1 Yayoi, Bunkyo-Ku, Tokyo 113-8657
Japan

USAID
USAID Regional Development Mission-Asia
Bangkok, Thailand

Dr Daniel Schar
Senior Regional Emerging Infectious Diseases Advisor

Dr Sudarat Damrongwatanapokin
Regional Animal Health Advisor

Dr Anchalee Jatapai
GHSA Advisor

WorldFish **Mr Partho Pratim Debnath** Aquaculture Specialist-Aquatic Animal Health WorldFish Dhaka, Bangladesh
IV. Others
Dr Channarong Rodkhum Department of Veterinary Microbiology Faculty of Veterinary Science Chulalongkorn University Pathumwan, Payathai Bangkok, 10330, Thailand **Dr Rungtip Chuanchuen** Head, Department of Veterinary Public Health Faculty of Veterinary Science Chulalongkorn University Pathumwan, Payathai Bangkok, 10330, Thailand **Dr Saharuetai Jeamsripong** Department of Veterinary Public Health Faculty of Veterinary Science Chulalongkorn University Pathumwan, Payathai Bangkok, 10330, Thailand
V. Organizers/secretariat
FAO–RAP **39 Phra Athit Road** **Bangkok, Thailand** **Mr Miao Weimin, Aquaculture Officer** **Dr Carolyn Benigno** **Dr Mary Joy Gordoncillo** **Dr Susana Siar** **Dr Masami Takeuchi** **Mr Domingo Caro**
NACA **Suraswadi Building, Department of Fisheries Compound** **Kasetsart University Campus, Ladyao, Jatujak** **Bangkok 10900, Thailand**

Dr Eduardo M. Leaño, Coordinator, Aquatic Animal Health Programme
Dr Cherdsak Virapat, Director General
Dr Derun Yuan, Coordinator, Training and Education
Mr Simon Wilkinson, Coordinator, Information and Communication
Ms Wella Udomlarp, Administrative/Finance Officer
Ms Lyn Pothimon, Secretarial
Ms Patcharaut Ponglumyai, Secretarial

Annex 3 Antimicrobial use in aquaculture: Important bacterial diseases of aquatic animals

Eduardo M. Leaño
Network of Aquaculture Centres in Asia-Pacific, Bangkok, Thailand

Introduction

AMR poses a fundamental threat to human and animal health, development and security. It occurs when pathogens undergo adaptive evolutionary changes that enable them to withstand antimicrobials (World Bank Group, 2017). Every use of antimicrobials in all food production sectors creates opportunities for the development of AMR, and this is more apparent when antimicrobials are overused or misused. The consequences of the development of resistance to antimicrobial agents are potentially severe, with a real risk of losing treatment options which could jeopardize not only human and animal health, but also global food safety and food security (OIE, 2016). In aquaculture, the use of antimicrobials has been practised for several decades in response to many devastating disease outbreaks. They have been used either as prophylaxis for disease prevention or for treatment when disease outbreak occurs.

Several transboundary aquatic animal diseases have swept the region over the past 30 years causing massive economic and social losses. They are mainly the result of transboundary movement (trading) of aquatic animals, especially in live form, which can lead to the introduction of new or emerging pathogens and may pose risks to the importing country's aquatic animal health status. The spread of these transboundary aquatic animal diseases clearly demonstrates the vulnerability of the aquaculture industry, as well as the wild fish populations, to disease emergence where impacts have been exacerbated by the lack of effective preparedness and response when diseases emerge.

In most intensive aquaculture production systems, AMR can develop in the culture water or fish gut bacteria due to antimicrobial therapy or contamination of the aquatic environment with human or animal wastes (Wall et al., 2016). However, the extent and persistence of antimicrobial residues in aquatic systems are unknown and current evidence is conflicting. Water is an important vehicle for the spread of both antimicrobial residues and resistance determinants because contaminated water can be consumed directly by humans and livestock and used to irrigate crops (Wall et al., 2016). Therefore, minimizing the emergence and spread of AMR requires coordinated, focused, multisectoral and multinational efforts.

Antimicrobial use in aquaculture

The availability of antibiotics has produced a total revolution in our thinking about the control of infectious diseases, including those in aquaculture. Antibiotics are considered a 'magic bullet', i.e. drugs that can attack invading bacteria without affecting the host (fish and shrimps in the aquaculture domain). Commonly used antibiotics in aquaculture are summarized in Table 1, some of those in the list are already banned for use in some countries in the region.

Table 1. Commonly used antibiotics in aquaculture

Antibiotics	Dose rate (mg/kg body weight/day)	Treatment period (days)
Furazolidone	110	5
Niturpirinol	0.8–3.5	5–10
Oxolinic acid	10	5–10
Oxytetracycline	75	10
Sulphamerazine	110–220	5–10
Trimethoprim/sulphadiazine	30	5–7

Source: http://www.aquatext.com/tables/antibiot.htm

The paradox is that the more we use antibiotics, the more they become ineffective due to the development of AMR by most bacterial pathogens. Moreover, the situation is aggravated by the unregulated use of antibiotics in the aquaculture sector in the region because dispensing can be done without any veterinary prescriptions. Application of antimicrobials at the farm level also lacks supervision from CAs and/or certified extension workers, thus the farmers are left to apply the drugs and other chemicals by themselves. Antimicrobials are usually applied by feed incorporation (in nurseries and grow-out ponds) or applied directly to the culture water (in hatcheries). In most cases, farmers often use antimicrobials upon the instructions of the drug dealers, thus they are not aware of the actual dosages that they have used or are using.

With the increasing concerns on the development of AMR among bacterial pathogens in aquaculture and related industries under the One Health initiative, judicious use of antimicrobials has been recommended and promoted in recent years. However, this is easier said than done considering the complexity of aquaculture systems, operations and culture environments. The key issue for the prudent use of antimicrobials is to know what the enemies are, and in the case of antibiotics they are bacteria. Infectious bacterial pathogens tend to adapt to stressful environmental conditions, for example the presence of chemicals or antibiotics in the culture environment. Continuous exposure of the population to these chemicals (especially at sublethal dosages) will result in the emergence of resistant populations or what we know as AMR. Antimicrobial-resistant bacterial pathogens can become more infectious and can cause more severe disease outbreaks and production losses.

Important bacterial diseases of fish and shrimps

Given that bacteria can survive well and are ubiquitous in both marine and freshwater aquatic environments, bacterial diseases have become a major challenge to aquaculture production, especially at warmer water temperatures. Bacterial species belonging to at least 13 genera have been reported to be pathogenic to aquatic animals, including: (1) Gram-negative bacteria such as Aeromonas, Edwardsiella, Flavobacterium, Francisella, Photobacterium, Piscirickettsia, Pseudomonas, Tenacibaculum, Vibrio and Yersinia; and (2) Gram-positive bacteria such as Lactococcus, Renibacterium and Streptococcus (Klesius and Pridgeon, 2011).

In this report, the following diseases caused by some of these bacterial pathogens are presented:

- Vibriosis in marine fish;
- Motile aeromonads septicaemia (MAS) in freshwater fish;
- Enteric septicaemia of catfish (ESC); and
- Acute hepatopancreatic necrosis disease (AHPND) of marine shrimps.

Vibriosis in marine fish. Vibriosis is caused by a group of bacteria belonging to the genus Vibrio, which are Gram-negative and teem in marine and estuarine environments. Vibrios usually abound in warm (>15 oC) saline and estuarine aquatic environments and present a constant threat to many cultured marine finfishes. The main species involved are *V. anguillarum, V. salmonicida and V. vulnificus.* They affect various species of economically important cultured marine fishes (Mohamad et al., 2019). Affected fish show lethargy with necrosis of skin and appendages leading to body malformation, slow growth, internal organ liquefaction, blindness, muscle opacity and mortality (Yasin et al., 2019). Mortalities (in severe cases/outbreaks) can be as high as 100 percent. For disease prevention and control, the use of antibiotics is strongly discouraged due to development of AMR and accumulation of residual antibiotics in fish tissues. A combination of control measures, particularly disease-free fish sources, farm biosecurity, improved water quality and other preventive measures such as vaccination might be able to control the infection (Yasin et al., 2019). Other alternatives to the use of antimicrobials include immunostimulants, probiotics and quorum sensing.

MAS in freshwater fish: MAS is an acute, subacute or chronic infectious disease of all freshwater fishes, especially cultured species such as carps, catfish, snakehead and tilapia. The disease is caused by the motile Aeromonas group including *A. hydrophila, A. cavieae and A. sobria. Aeromonas* species are opportunistic pathogen-causing diseases in fish under stress and they produce pathogenic factors including haemolysin and aerolysin, which provoke the disease. Predisposing factors for disease development include stress due to high temperature, overcrowding and low dissolved oxygen, malnutrition, heavy infestation of parasites, organic pollution, physical injuries, and rough handling and transportation. The disease is manifested clinically with haemorrhages, ulcerations, abscesses, ascitic fluid, anaemia and high mortality (Stratev and Odeyemi, 2017). As Aeromonas are common in any freshwater environment, their elimination from the fish-rearing system is impossible. Thus, as in other bacterial diseases of aquatic animals where the use of antibiotics is not recommended, better water and feeding management (reduction of stressors), as well as the use of alternatives to antibiotics can successfully minimize if not prevent disease occurrence.

ESC: ESC is a highly infectious bacterial disease of the catfish family (including pangasius catfish), caused by the Gram-negative bacterium *Edwardsiella ictaluri.* Problems associated with epizootics include high mortality rates, increased susceptibility to disease and high treatment costs. ESC or popularly known in Viet Nam as Bacilliary necrosis of Pangasianodon (BNP) may occur in fish of all ages, although fingerlings and juvenile fish especially seem to be affected (Dung, 2010). Disease occurs mainly during the rainy season when water temperatures are in the range of 23 to 30 In general, crowding, mixing and adverse climatic conditions are risk factors for the development and spread of ESC (Crumlish *et al.,* 2002; Yuasa *et al.,* 2003). Behavioural signs of affected fish included reduced feeding activity, listless swimming at the pond surface, spiralling and occasional rapid swimming at the pond surface. Acute infection is characterized by enteritis and septicaemia with rapid mortality as early as two days postexposure, while chronic infection is characterized by meningoencephalitis with 'hole-in-the-head' lesions. Prevention of ESC is difficult because of its widespread distribution throughout the catfish industry. Various management practices, however, can reduce the incidence and impact of ESC. These include reducing stress, and proper nutrition and feeding practices (Chappel, 2008).

AHPND of marine shrimps: This shrimp disease causes unusually heavy mortality in cultured shrimps at approximately 30 to 45 days of culture. The disease is caused by a highly virulent strain of *Vibrio parahaemolyticus* (Tran et al., 2013) carrying plasmids containing the genes that code for the toxins pirA and pirB (Han et al., 2015; Lee et al., 2015). Recently, other Vibrio species have been found to contain the same toxin plasmid found in *V. parahaemolyticus* and can also cause the same disease signs. These species include *V. harveyi* (Kondo et al., 2015), *V. owensii* (Liu et al., 2015), *V. campbellii* (Dong et al., 2017) and *V. punensis* (Restrepo et al., 2018). Clinical signs observed included slow growth, corkscrew swimming, loose shells and pale colouration. Affected shrimp also consistently showed an abnormal hepatopancreas (HP) (shrunken and discoloured). The key diagnostic feature needed for confirmation is the medial sloughing off of HP cells as seen in histological sections of the affected shrimp's HP (Flegel, 2012; Leaño and Mohan, 2012). With the increasing incidence of AMR among important shrimp bacterial pathogens, including *V. parahaemolyticus,* better practices have been implemented by shrimp farmers to avoid the use of antimicrobials (often not effective) which include:

- Improved AHPND detection which has paved the way in the supply of 'clean' shrimp broodstock and postlarvae (PLs);
- Improved AHPND prevention by management changes, which focus more on environmental (and feeding) management and biosecurity measures; and
- Improvement of broodstock health status and the production of healthy (more resistant) PLs for grow-out culture.

Conclusion

Outbreaks of important and emerging aquatic animal bacterial diseases will likely continue with the continuous expansion or intensification of aquaculture systems and the introduction of new species for culture. The risks associated with these emerging and transboundary diseases are shared, as countries in the region have shared waterbodies and epidemiological links through trade and transboundary movement of live aquatic animals. On the other hand, the use of antimicrobials and other drugs is strongly discouraged along the production chain, due to AMR and food safety concerns. AMR poses a fundamental threat to human and animal health, development and security. It occurs when pathogens undergo adaptive evolutionary changes that enable them to withstand antimicrobials (World Bank Group, 2017). Every use of antimicrobials in all food production sectors creates opportunities for the development of AMR, and this is more apparent when antimicrobials are overused or misused. The consequences of the development of resistance to antimicrobial agents are potentially severe, with a real risk of losing treatment options which could jeopardize not only human and animal health, but also global food safety and food security (OIE, 2016). Therefore, a collaborative approach in dealing with important diseases of aquatic animals, usage of antimicrobials and AMR is warranted and highly necessary for better aquatic animal health management.

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Annex 4 Regional overview on current laws and regulations relevant to AMU and AMR

Aihua Li
Institute of Hydrobiology, Chinese Academy of Sciences,
Wuhan, P.R. China, 430072

Introduction

Uncontrolled use of antibiotics for disease control and treatment or growth stimulation in aquaculture has increased bacterial resistance to antibiotics that can reach humans through the food chain. Establishment and implementation of regulations and guidelines are considered as key components in addressing the abuse, overuse, misuse and release of antimicrobials, and play a vital role in regulating and reducing unnecessary antimicrobial use to minimize the risks of AMR. In addition, over-the-counter sale or over-the-Internet sale of antibiotics is a common practice in many countries. This phenomenon complicates the regulation of the medical use of antibiotics.

In general, most countries in the Asia-Pacific region have implemented sound legal requirements that establish a framework for all aspects of aquaculture drugs. The registration, production, marketing, use of antimicrobial agents, antibiotic resistance surveillance and monitoring, the establishment of MRLs, and monitoring of antibiotic residues in aquatic animal species are controlled by laws, regulations and policies, which vary significantly in different countries.

The roles of legislation comprise turning policy objectives into clear obligations and making them sustainable, clarifying roles and responsibilities of governments and stakeholders, setting up mechanisms for coordination, introducing regulatory mechanisms (licences, permits), regulating inspections and penalizing violations.

What legislation can do for aquaculture includes approving or prohibiting the access and use of certain antimicrobial agents for animals, regulating counterfeit antimicrobials, regulating the use of antimicrobials as growth promoters, governing the prevention, control and monitoring of infectious diseases, monitoring the quality of veterinary medicines, setting up GAPs, potentially controlling wastes contaminated with antimicrobials and controlling residues of antimicrobials in food, feed, water and soil.

Legal frameworks relevant to AMU and AMR in the Asia-Pacific region

In China, there are various laws and regulations governing AMU and AMR. These laws embrace fishery operations, livestock epidemiology, agricultural product quality and safety as well as environmental protection that also encompasses antimicrobial pollution prevention. Regulations govern veterinary pharmacopoeia as well as the administration of veterinary drugs, feed and feed additives. In addition, a series of announcements, gazettes or notices is issued by the Ministry of Agriculture and Rural Affairs regarding banned veterinary drugs, the prohibition of certain types of veterinary drugs in livestock and the establishment of MRLs for veterinary drugs in animal food. There is also a national surveillance programme for AMR in livestock.

There are many related legal thrusts such as 'The whole nation's special rectification action plan on antibiotics', 'Banned compounds and veterinary drug residue exceeding the standards in livestock and aquatic products', 'Annual special rectification actions on veterinary drugs' (since 2011), 'Five-year action plan for veterinary drug (antimicrobials) integrated governance' (since 2015), and 'Strengthening the punishment of illegal use of drugs in livestock and aquaculture'. These mechanisms have been conducted every year on a regular or irregular basis. The National Consultative Expert Commission of AMR Containment and Veterinary Drug Residues was established in 2017. A guideline 'Management Methods for Clinical Application of Veterinary Antimicrobial Drugs Used in Food Animals (draft)' has been published. A nationwide monitoring network for prevention of epidemics among aquatic animals has been in place for many years. Twelve national technical standards for GAPs have been formulated and published. The National Action Plan to Contain AMR (2016 to 2020) was promulgated in 2016. Based on this action plan, the National Action Plan to Contain AMR of Animal Origin (2017 to 2020) was also promulgated by the Ministry of Agriculture in 2017. In summary, these laws and regulations cover all aspects related to AMU and AMR, including disease control, manufacture of veterinary antibiotics, AMU/AMR surveillance, residues/withdrawal periods, growth promoters and GAPs.

Bangladesh has laws and policies, such as the fish and animal feed law, the fish and shrimp hatchery law, the code of conduct for the aquaculture-based shrimp industry, and fish and fish products' inspection and quality control rules. The mechanisms are backstopped by the drug (control) ordinance, national drug policy, national strategy for AMR containment and the road map of the national action plan for AMR control.

India has issued regulations on the registration of farms, hatcheries and farm inputs; food safety and standards, such as MRLs for contaminants, toxins and residues; the national policy for the containment of AMR; a directive from the Coastal Aquaculture Authority (CAA) on the use of antibiotic-free aquaculture inputs in shrimp farms and hatcheries; and an advisory on the use of antibiotics in livestock. Concerted effort is being made to develop information on the safety, efficiency, dosage, schedule and withdrawal period for selected groups of drugs in candidate aquaculture species.

In Indonesia, regulations on fish medication, good manufacturing practices of fish medicines, livestock husbandry, and animal health are observed, while in Myanmar, a fisheries law and an animal diseases act are implemented.

In Japan, veterinary medicinal products (VMPs) are directly controlled by law (the Pharmaceutical Affairs Law). The Ministry of Agriculture, Forestry, and Fisheries controls VMPs exclusively used for animals under this law. Almost all aspects pertaining to VMPs are covered by this law and associated regulations.

In Malaysia, the Feed Act and Regulation (Act 968), Malaysian Quarantine and Inspection Services Act (Act 728) and the Poison Act are in place for livestock husbandry. Regulations do not specify antibiotics to be used in aquaculture. A list of approved antibiotics and MRLs is not available in Malaysia.

In the Philippines, administrative orders relative to regulation on AMU govern the veterinary domain; animal feed and feed products; surveillance of registered health products, licensing of local vaccine manufacturers and so forth. Manufacturers, importers, suppliers, distributors and retailers of these products are under the purview of the Animal Feeds Standard Division that prescribes requirements for veterinary drugs and products, dispenses them and recruits veterinary consultants for liaison with commercial animal feed manufacturers; the national veterinary drug residue control programme, interagency committees and implementing guidelines in this context are in place.

In Thailand, there are regulations on the code of practice for control of the use of veterinary drugs, animal feed quality and GAPs. The registration, import, marketing and use of veterinary medical products are regulated by laws or policies. Programmes to monitor drug residues in animal products and AMR surveillance of aquatic animals and aquaculture settings are implemented.

In Viet Nam, the Ministry of Agriculture and Rural Development and counterpart offices have issued a set of circulars or decisions on AMU and AMR. These departments are responsible for publishing lists of veterinary medicines approved for circulation in Viet Nam and lists of prohibited chemicals and antibiotics in aquaculture. They have also established committees on drug resistance surveillance; managing and supervising imported antibiotic materials for the production of veterinary medicine; regulating all aspects of veterinary management; regulating the quarantine of animals and fisheries products; managing and supervising imported antibiotic materials for the production of veterinary medicine; completely eliminating antibiotic supplements in animal feed (since 2020); approving the National Action Plan against Drug Resistance; establishing the National Steering Committee on the Prevention of AMR; publishing a list of banned antibiotics in aquaculture (24 antibiotics, updated annually); and developing and implementing the national programme for strict control of antibiotic raw materials in veterinary medicine production. For disease control and best practices, legislation encompasses the amended fisheries law; implementation of Vietnam good agricultural practices (VietGAP); a set of decisions for the national programme on the prevention and control of diseases in pangasius catfish (2015 to 2020); the national programme for establishment of disease-free compartments and zones for shrimp production; the national programme for active surveillance of diseases in shrimp and pangasius catfish and products to be exported between 2017 and 2020; and circulars regarding the prevention and control of fishery diseases and the regulation of the quarantine of livestock and fisheries products.

Gaps and issues

Inadequate specific regulations on the management of antibiotic use in aquaculture and lacklustre concern about diffusion of AMR originating from aquaculture are common among most countries in the Asia-Pacific region. Most countries also lack sufficient restrictions on the sale of aquatic antibiotics resulting in free access to antimicrobial agents via multiple channels for farmers. Surveillance programmes in many countries to monitor antibiotic residues in aquatic products are implemented but have no corresponding legal provisions for punishment when noncompliance is detected.

At the legislative level, there is lack of attention to the discharge and treatment of aquaculture wastewater contaminated with antimicrobial drugs.

Each country has a list of approved and banned antimicrobials for aquaculture but the differences in the variety of antimicrobial agents allowed among countries in the region are significant and there is no comprehensive list of approved and banned antimicrobial agents.

Recommendations

The sources of antibiotic-resistant bacteria and genes must be considered in developing AMR control strategies rather than those originating from AMU in aquaculture, such as water sources, seed, feed (including fishmeal, frozen fish and trash fish), probiotics and livestock manure. As such, stronger action is needed for enforcement of AMU- and AMR-related laws and regulations. FAO and NACA should cooperate with countries in this region to harmonize regulatory requirements.

Annex 5
Country case study reports

Country case study 1 Assessment report on AMU and AMR risk in aquaculture in China

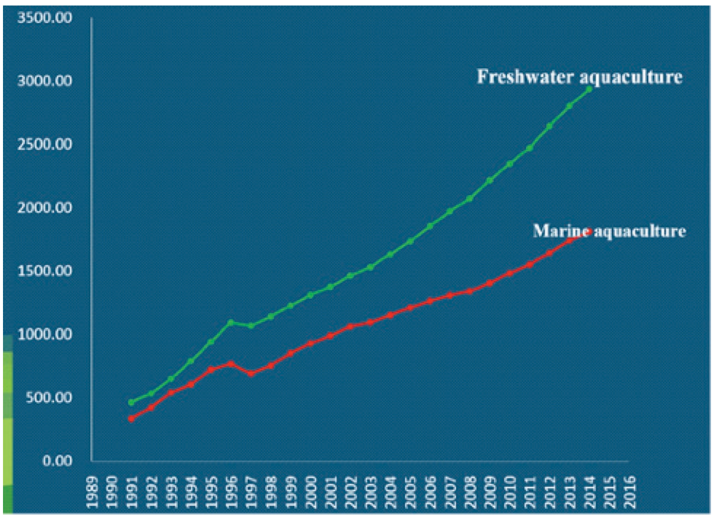
Kun Hu
Shanghai Ocean University, Shanghai,
P.R. China

Introduction

The People's Republic of China has made outstanding achievements in fishery development and the aquaculture industry has expanded rapidly. This has not only successfully addressed the problem of safe fish consumption among urban and rural residents, but also safeguarded national food security, enhanced livelihoods, increased farmers' income and improved environmental water quality. Aquaculture is an important component of Chinese agriculture and the sector supports a large consumer market and export trade. Approximately 8.5 million ha encompassing ponds, lakes, reservoirs, rivers and rice paddies are used for aquaculture in China.

China's aquaculture production is mainly distributed in coastal provinces and some inland provinces. Annual production in Shandong, Guangdong, Fujian, Zhejiang, Liaoning, Jiangsu, Hubei, Guangxi, Anhui, Jiangxi and Hunan provinces accounts for 90 percent of the country's total output. Details are shown in Figure 1 and Table 1.

Figure 1. Trends in aquaculture production (in thousand tonnes) in China from 1991 to 2014



Source: Bureau of Fisheries, 2017. Chinese fisheries statistic yearbook. Beijing, Agriculture Press, 2016.

Table 1. Aquaculture production in China (2015 and 2016)

Indicators	2016 (million tonnes)	2015 (million tonnes)
Total Fisheries products	**69.0**	**67.0**
Aquaculture products	51.4	49.4
Mariculture	19.6	18.8
Freshwater aquaculture	31.8	30.6
Fish	29.5	28.5
Crustaceans	4.4	4.1
Shellfish	14.5	13.8
Algae	2.2	2.1
Others	0.9	0.85

Source: Bureau of Fisheries, 2017. Chinese fisheries statistic yearbook. Beijing, Agriculture Press, 2016.

The aquaculture area in China was approximately 7 million ha in 2017, an increase of 0.05 percent over the previous year. The mariculture area was approximately 2 million ha representing a decrease of 0.67 percent, while the freshwater aquaculture area was 5 million ha, an increase of 0.33 percent. The mariculture and freshwater aquaculture area ratio is 28:72. Total national aquaculture production in 2017 was 50 million tons (MT), of which fish accounted for 30 MT, crustaceans 4.5 MT and shellfish 14.5 MT. Total mariculture production was 20 MT, an increase of 4.46 percent, while total freshwater aquaculture accounted for 30 MT, an increase of 0.95 percent. The total production of marine farmed fish was 1.5 MT, an increase of 8.44 percent, and the total production of freshwater farmed fish was 25 MT, an increase of 0.03 percent. Mariculture crustaceans accounted for 1.6 MT, an increase of 8.44 percent, while 3 MT of freshwater cultured crustaceans were produced, an increase of 11 percent.

Bacterial diseases are a major problem in aquaculture production in China, as summarized in Tables 2 and 3.

Competent authorities

The Bureau of Fisheries, Ministry of Agriculture and Rural Affairs (MARA) is responsible for studying and initiating development strategies, programmes and plans, introducing technical innovations and making major policy suggestions on fisheries. It also drafts related laws, regulations and provisions, organizes their supervision and implementation, administers fishery standards, quality and safety, participates in the formulation and implementation of international fishery treaties and multilateral and bilateral fishery agreements, and organizes international fishery information exchanges and cooperation. It is responsible for fishery statistics and the release of related information.

Table 2. Pathogenic Gram-negative bacterial pathogens of aquatic organisms in China

Pathogens	Diseases	Susceptible hosts
Aeromonas hydrophila and other Aeromonas spp.	Motile aeromonads septicaemia (MAS)	Catfish, carps, trout, eel, sturgeons, tilapia, bass
A. salmonicida	Furunculosis	Salmon, trout, carps, catfish
Edwardsiella ictaluri	Enteric septicaemia of catfish	Catfish
E. tarda	Edwardsiellosis or putrefactive disease	Turbot, flounder, carps, catfish, eel, tilapia
Flavobacterium columnare	Columnaris	Carps, mandarin fish, trout, tilapia, catfish, salmon
F. psychrophilum	Flavobacteriosis	Trout
Citrobacter spp.		Carps, sturgeon, crabs, cray-fish, soft-shelled turtles
Acinetobacter spp.		Sturgeons
Photobacterium spp.	Pasteurellosis	Sturgeons, sea bream, yellow catfish, seabass, snakeheads
Pseudomonas spp.	Pseudomonads septicaemia	Carps, catfish, eel, salmon
Vibrio spp.	Vibriosis	Marine fish, crayfish
Yersinia ruckeri	Yersiniosis or enteric red mouth disease	Trout, salmon

Source: Ministry of Agriculture, P.R. China.

The Veterinary Bureau of the MARA is responsible for organizing and drawing up development strategies, programmes and plans for veterinary medicine and drugs, veterinary medical appliances, drafting laws, regulations and provisions for the administration of veterinary medicine and drugs and animal quarantine, evolving related policies and organizing their implementation.

The National Fisheries Technology Extension Center (NFTEC) is a subordinate body of the Veterinary Bureau, MARA. It is tasked with the formulation of the national aquatic technology promotion plan and implementation, guiding the development of the national aquatic technology extension system, organization of the fisheries development strategy and policy research, introduction of key fisheries technology, fisheries science and technology exchange and cooperation, aquaculture disease prevention and control, as well as aquatic plant and animal disease surveillance and epidemiological investigation.

Table 3. Pathogenic Gram-positive bacteria affecting aquatic organisms in China

Pathogens	Diseases	Susceptible hosts
Lactococcus garvieae	Lactococcosis	Flounder, soft-shelled turtle, crayfish
Nocardia sp.	Nocardiosis	Snakeheads, large yellow croakers, amberjacks, largemouth bass, pompano

Pathogens	Diseases	Susceptible hosts
Streptococcus agalactiae	Streptococcosis	Tilapia, groupers
S. iniae	Streptococcosis	Tilapia, sea bream, flounder, hybrid striped bass
S. dysagalactiae	Streptococcosis	Sturgeons
Weissella sp.	Haemorrhagic septicaemia	Trout
Mycobacterium spp.	Fish tuberculosis	Sturgeons

Source: Ministry of Agriculture, P.R. China.

MARA has carried out safety risk monitoring of national agricultural product quality (including aquatic products) since 2001. The Department of Technology and Quality Supervision (DTQS), Fisheries Bureau, MARA, is responsible for the organization and implementation of the programme.

National regulations related to AMU and AMR for aquaculture

The legal framework relevant to AMU and AMR in China includes the Fisheries Law (2013 Amendment), the Animal Epidemic Prevention Law, the Agricultural Product Quality and Safety Law, the Environmental Protection Law (involving antimicrobial pollution in environment) as well as regulations on veterinary pharmacopoeia, administration of veterinary drugs and administration of feed and feed additives. These are supplemented by Announcements, Gazettes or MARA Notices. For example:

- List of veterinary drugs banned by the Ministry of Agriculture of China – Bulletins Nos. 176, 193 and 1519 of the Ministry of Agriculture;
- Banning of four veterinary drugs (lomefloxacin, ofloxacin, norfloxacin, levofloxacin) in food animals – Bulletin No. 2292 of the Ministry of Agriculture (2015/9/1);
- Banning of colistin sulphate as a premix for animal growth promoters –Bulletin No. 2428 of the Ministry of Agriculture (2016/7/26);
- MRLs of Veterinary Drug in Animal Food (2002) – Bulletin No. 235 of the Ministry of Agriculture;
- Ban on arsanilic acid, roxarsone and olaquindox as drug feed additives in food animals (draft recommendation);
- National surveillance programme for AMR of animal origin (since 2018; for aquaculture since 2015);
- Annual national implementation programme of the veterinary drug residue monitoring plan (1999);
- MRLs of veterinary drugs in animal products (24 December 2002) (under revision);
- National rectification action plan on antibiotics, banned compounds and veterinary drug residues exceeding standards for livestock and aquatic products (July 2017);

- Establishment of a National Consultative Expert Commission on Antimicrobial Resistance Containment and Veterinary Drug Residues (May 2017);
- Annual special rectification actions on veterinary drugs (since 2011);
- Five-year action plan for veterinary drug (antimicrobials) integrated governance (since 2015);
- Strengthening the punishment of illegal use of drugs in livestock and aquaculture;
- Publication of 'Management Methods for Clinical Application of Veterinary Antimicrobial Drug Used in Food Animals ' (draft); and
- Establishment of a monitoring network for epidemics among aquatic species.

Antimicrobial use in aquaculture

Chemotherapy is one of the three major measures for the control of aquatic animal diseases, and it is considered as the most direct and effective method. The application of fishery drugs has played an important role in aquaculture.

Antimicrobial use in aquaculture: At the beginning of the 1960s, antimicrobials and Chinese herbal medicine began to be used in the prevention and control of aquatic animal diseases. Sulphanilamide, oxytetracycline, aureomycin, erythromycin and streptomycin were successively applied for the prevention and treatment of bacterial fish disease. Meanwhile, Chinese herbal medicines, such as Rheum palmatum L., Sapium sebiferum, Euphorbiae humifusae, Polygonum hydropiper, Folium isatidis, Radix isatis and Andrographis paniculata have also proven effective in preventing and controlling bacterial diseases of fish. In the late 1980s, fishery drugs in China were introduced into the registration system but only drugs that had been evaluated for safety and efficacy could be used for aquaculture. The first licensed antimicrobial used for aquaculture was a furazolidone preparation which is now on the list of banned antimicrobials. A stricter veterinary drug registration system has been in place since 2004 and can only be carried out by MARA.

Currently, there are 11 antimicrobials which are legally allowed for use in aquaculture in China. They belong to four classes of antibiotics: aminoglycosides, quinolones, sulphonamides and tetracyclines. In addition, there are 74 herbal medicine preparations which meet the national standard for use in aquaculture. In many cases, herbal medicines are used combined with antibiotics to reduce the dose of the latter and for better therapeutic effect.

Aquaculture species: More than 50 species of aquatic organisms are used for large-scale breeding in China; large-scale farming, deep-water cage culture and ecological farming are developing rapidly. Cultured species are diverse and of high quality.

Estimated quantity of antibiotics and cost per unit of aquaculture per year: In China, it is estimated that 82 240 tonnes of antibiotics are used for livestock and poultry annually (including aquaculture). According to incomplete statistics, there are approximately 160 fishery drug manufacturers certified for international good manufacturing practices. Currently, there are more than 100 national quality standards for fishery drugs as well as Chinese herbal medicines and immunostimulants. The annual sales volume of fishery drugs is 150 000 tonnes valued at CNY 1.5 billion.

Antimicrobials approved and banned in aquaculture

The Ministry of Agriculture has published a list of drugs that are banned from use in feed and animal drinking water. The list contains five categories of 40 types of drugs (Table 4). Antibiotics banned in aquaculture in China include: norfloxacin; ciprofloxacin; erythromycin; chloramphenicol; tylosin; bacitracin zinc; nitrofurans (furazolldone, nitrofurazon, nitrofurantoin, etc.); olaquindox.

Table 4. Banned drugs and chemicals for use in feed and animal drinking water

Categories	Drugs and chemicals
Adrenergic receptor agonists	Clenbuterol hydrochloride, salbutamol salbutamol sulphate, ractopamine, dopamine hydrochloride, cimaterol, terbutaline sulphate
Reproductive hormones	Diethylstilbestrol, estradiol, estradiol vacate, estradiol benzoate, chlorotrianisene, ethinylestradiol, quinestrol, chlormadinone acetate, levonorgestrel, norethisterone, chorionic gonadotrophin, menotropins
Protein anabolic hormone	Iodinated casein, nandrolone phenylpropionate
Mental medicines	Chlorpromazine hydrochloride, promethazine hydrochloride, diazepam, phenobarbital, phenobarbital sodium, barbital, amobarbital, amobarbital sodium, reserpine, estazolam, meprobamate, midazolam, nitrazepam, oxazepam, pemoline, triazolam, zolpidem

Source: Agricultural Industry Standard, P.R. China.

National action plan/strategy on AMU and AMR

National Action Plan to Contain Antimicrobial Resistance (2016–2020) and the National Action Plan to Contain Antimicrobial Resistance of Animal Origin (2017–2020) were published successively by the central government and by MARA.

The major objectives of MARA's National Action Plan (NAP) include:

- The proportion of sales of antibacterial agents with veterinary prescriptions in the animal sector to be 50 percent in provinces (autonomous regions and municipalities);
- To optimize AMU/AMR surveillance networks. To set up AMR reference laboratories and bacterial strain banks. To establish an evaluation system for AMU and AMR;

- Antimicrobials shared by humans and animals or those of easily producing cross-resistance should be gradually withdrawn from the market for animal growth promoters;
- To effectively control the increasing trend of main animal origin antimicrobial-resistant bacteria; and
- To develop and implement educational efforts to ensure that medical staff, veterinarians and livestock farmers receive information and training on the rational use of antibacterial agents.

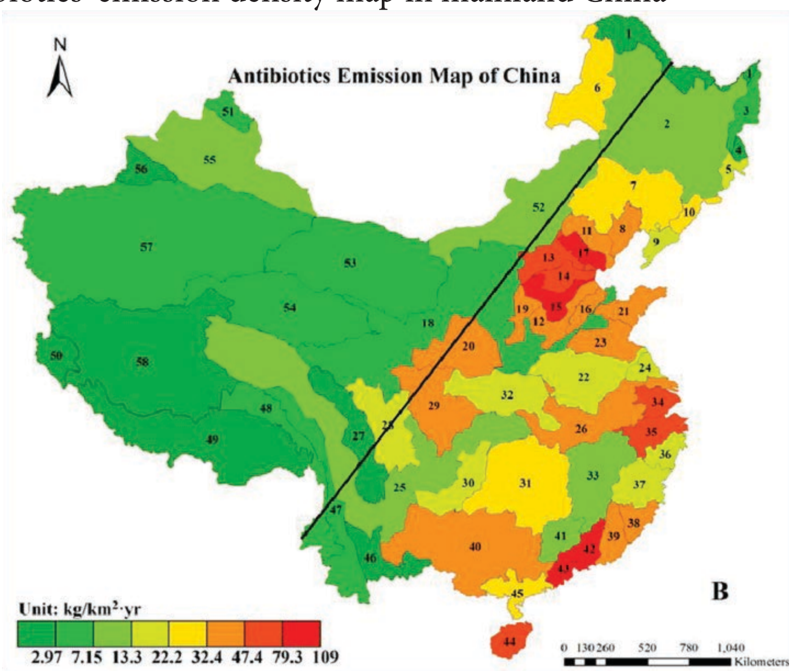
Concrete measures are being promoted for the gradual withdrawal of antimicrobial agents for growth promotion; strengthening of the supervision and management of the approval, production and use of veterinary antimicrobial drugs; improvement of the monitoring system for bacterial resistance of animal sources; strengthening of the monitoring of veterinary antimicrobial residues in animal products; reduction in the use of veterinary antimicrobial agents in animal feed (including aquaculture); and enhanced training of practitioners, public awareness and education. Strengthening capacity development on information, standards, science and technology support, and international cooperation are also part of the agenda.

The major strategies and actions of the NAP include increasing investment in research and development on antimicrobials; strengthening the antibacterial agent application and AMR control system; optimizing the antimicrobial consumption and antimicrobial resistance surveillance system; improving the capacity of professional personnel in AMR prevention and control; strengthening the prevention and mitigation of environmental pollution by antimicrobials; strengthening awareness raising and education on AMR; and conducting extensive international exchanges and cooperation.

Monitoring and surveillance of AMU and AMR

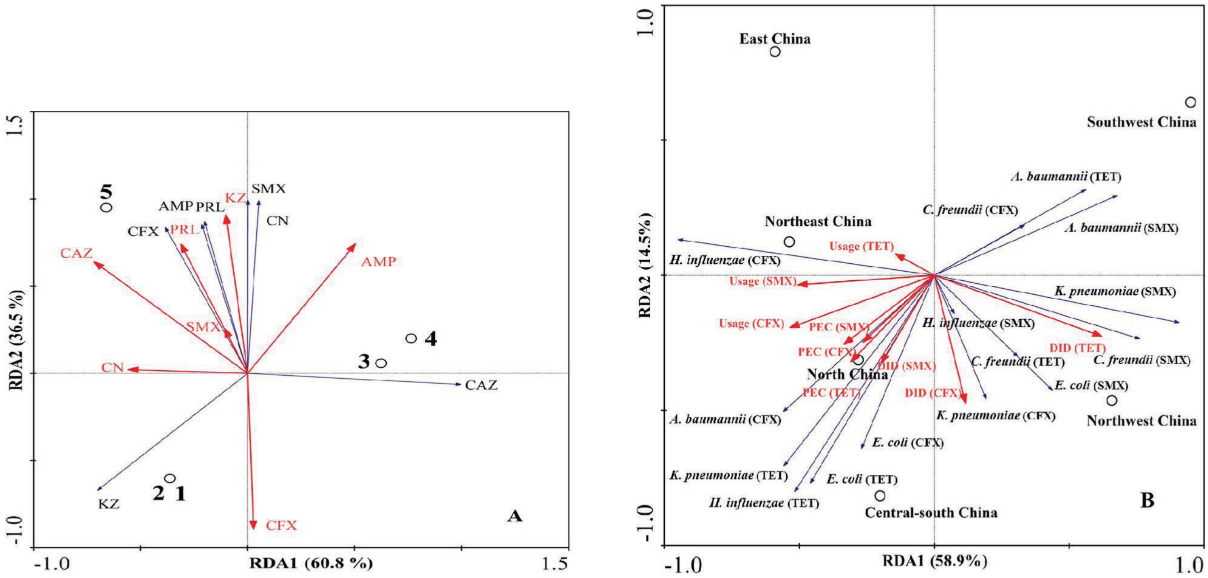
The antibiotics' emission density in mainland China is shown in Figures 2 and 3.

Figure 2. Antibiotics' emission density map in mainland China



Source: Zhang *et al.*, 2015.

Figure 3. Redundancy analysis (RDA) showing relations of bacterial resistance to seven respective antibiotics in hospitals and rivers (left) and the relations between hospital bacterial resistance rates and antibiotic usages (right). Left: The blue and red lines represent the resistance to Escherichia coli in hospitals and rivers; empty circles 1, 2, 3, 4 and 5 represent the Pearl River, Dongjiang River, Haihe River, Liaohe River and Yellow River, respectively. The bacterial resistance data in the hospitals are selected from the city hospitals through which these rivers flow. RDA 1 and RDA 2 explained 61.5 percent and 34.4 percent of the total variance, respectively. Right: The bacterial resistance data of five bacteria from hospitals (blue lines), antibiotics' usage data including defined daily doses (DIDs)/1 000 capita/day) and regional total usages, and environmental concentrations (PECs) (red lines) are available for three respective antibiotics (CFX, SMX and TET). Empty circles represent the six regions of China. RDA 1 and RDA 2 explained 58.9 percent and 14.5 percent of the total variance, respectively.



Source: Zhang *et al.*, 2015.

There have been many investigations on the AMR status of fish pathogenic bacteria in China. AMR status and annual changes and resistance mechanisms (such as genes, R plasmids, integrons) of diverse fish pathogenic bacteria isolated from different regions, different aquatic animals and different aquaculture modalities have been studied by the academe and the national aquatic AMR surveillance programme organized by the National Fishery Technology Extension Center, MARA. In general, various species of Aeromonas and Vibrio are the predominant fish pathogenic bacteria for freshwater aquaculture and mariculture, respectively, so they have been the focus of AMR studies. The large number of fish species and other aquatic animals being cultured in China considerably increases the complexity of AMR and difficulty in controlling it. Currently, florfenicol, quinolone, neomycin, sulphonamides/trimethoprim and tetracycline are the major antibiotics used in Chinese aquaculture.

There are differences in AMR among different cultured species and different regions. In general, the proportion of drug-resistant bacteria originating from fish and shrimp was smaller than those from reptiles and ornamental fish, with sulphonamides as the least sensitive antimicrobials in most cases. AMR in cold-water fish and shellfish was less significant than other aquatic animals. Integron-mediated AMR plays a very important role in the population of aeromonads and vibrios. The Class I integron was more common than Class II and Class III. Gene cassettes, dfrA12, aadA2 and aac(6')-Ib-cr, encoding resistance to aminoglycosides, trimethoprim and quinolones, respectively, were the most common in the variable region of the Class I integron. ARGs can be enriched in pond sediment despite the lack of contemporaneous antibiotic use at the pond. To curb the deterioration of bacterial resistance in aquaculture, more strategies need to be developed in addition to the need for prudent and responsible use of antibiotics. For example, determining the possible sources of ARGs, especially mobilized ARGs, is essential for controlling the occurrence and spread of ARGs at fish-farming facilities and for lowering the risk of ARG spread from farms to surrounding environments.

Strategy and actions in addressing AMR risks in aquaculture

Antibiotic Residue Monitoring Programme for aquatic products: To implement the Agricultural Product Quality and Safety Law, to comprehensively grasp the quality and safety of agricultural products in China, and to strengthen agricultural product quality and safety supervision, the Ministry of Agriculture (MOA) has carried out a routine monitoring programme of national agricultural product quality (including aquatic products) (safety risk monitoring) since 2001. The DTQS is responsible for the organization and implementation of the programme. The standard for MRLs was published in 1997 and revised in 2002 by MARA (formerly the MOA). In this standard, there are 88 types of veterinary drugs (including those used in aquaculture) that do not require an MRL, 94 types with MRLs that need to be established, 9 types which can be used in food animals but for which residues cannot be detected and 31 types that are strictly prohibited. MARA issues regular monitoring of statistical information on the quality and safety of agricultural products quarterly.

Reducing the use of aquaculture drugs, especially antibiotics: Since 2017, the Chinese Government has encouraged and undertaken research on antibiotic-free fish-farming related technologies and promoted the use of alternatives to antibiotics in aquaculture (inter alia herbal medicines, probiotics, Biofloc technology, vaccines, antimicrobials and immunostimulants). Specific measures include timely and accurate disease diagnosis, correct selection of antibiotics based on antimicrobial sensitivity testing (AST) results, using appropriate dosages and duration, avoiding overdosage and extended treatment courses, and prohibiting prophylactic antibiotic and growth promoter use. Many new aquaculture technologies have been developed and applied to reduce the risk of fish diseases, and subsequently lower antibiotic use. Examples are: integrated multi-trophic aquaculture (IMTA), integrated ecological fisheries, bottom microporous aeration technology, the industrialized recirculating aquaculture system, deep-sea cage farming and so forth.

Aquatic animal disease monitoring network across the country: A comprehensive aquatic animal epidemic monitoring system has been established in China and has operated efficiently for many years. This system includes regional aquatic animal epidemic prevention laboratories, provincial aquatic animal disease control centres, 628 county aquatic animal disease prevention stations, one remote diagnosis system for aquatic animal diseases and one epidemic monitoring system (network) consisting of more 4 210 monitoring and reporting sites across the country.

AMR surveillance and monitoring programme: The NFTEC, MARA has been conducting a governmental project on AMR surveillance and monitoring in aquaculture since 2015. This surveillance covers 12 major aquaculture-producing provinces. Isolation and identification of the bacteria and AST are conducted by corresponding fisheries extension centres/stations in the provinces. Clinical and Laboratory Standard Institute (CLSI) breakpoints are directly used to interpret the results for fish bacteria in most studies. The online 'Analysis System of AMR Surveillance Data of Pathogenic Bacteria Isolated from Aquaculture Animals' developed by NFTEC and supported technically by Suzhou Jie'An Info Technology Co., Ltd. is being used for the analysis of surveillance data.

Prescription system for fishery drugs: The state exercises classified management over veterinary drugs. According to their safety and risk of use, veterinary drugs have been divided into prescription and nonprescription drugs since 2013. All antimicrobials are prescription drugs. But this system is not currently implemented very well. Fishery drugs including antibiotics can be purchased free from various sources without a veterinary prescription. China has been implementing a network of occupational veterinarians since 2011, but there are insufficient practising veterinarians to provide services for aquaculture.

Fish vaccines licensed or widely used in China: A number of fish vaccines are now produced and used locally. These are: *Edwardsiella tarda* (strain EIBAV1), an avirulent live vaccine for *Scophthalmus maximus* (turbot); *Aeromonas* hydrophilia (strain J1) for MAS of freshwater fish; the killed grass carp reovirus (GCRV) and attenuated grass carp reovirus; inactivated tissue homogenate vaccine made of tissues of *Ctenopharyngodon* idellus (grass carp) and *Mylopharyngodon piceus* (black carp) infected by GCRV; a multivaccine of anti-idiotypic antibodies against Vibrio alginolyticus, Vibrio anguillarum and *Edwardsiella tarda* for *Paralichthys olivaceus* (flounder); iridovirus (strain Ehime-1 and GF14) for Pagrus major, *Seriola spp.* and *Pseudocaranx dentex;* Lactococcus garvieae (strain BY1) for *Seriola* quinqueradiata. Several other fish vaccines are being developed, i.e. for streptococcosis of tilapia and edwardsiellosis of channel catfish and yellow catfish caused by *Edwardsiella ictaluri.*

Issues, gaps and constraints in the implementation of regulations and plans/strategies for AMU and AMR

In some areas, fish farmers still consider antibiotics as the most powerful method to control fish diseases. Therefore, regulations and their dissemination need to be strengthened.

Because the results from food surveillance are considered commercially sensitive, data on AMU and AMR are rarely released publicly by regulators. Mostly, legal regulations are not strictly enforced. In addition, antibiotics can be purchased easily without veterinarians' prescriptions from various sources and the use of antibiotics in aquaculture has no proper supervision. This is the biggest source of abuse of antimicrobials in aquaculture. Suboptimal GAPs in farming, including inferior disease diagnosis and drug use techniques, result in untimely and inaccurate treatment after a disease has occurred. These may be the root causes of anomalies in Chinese aquaculture.

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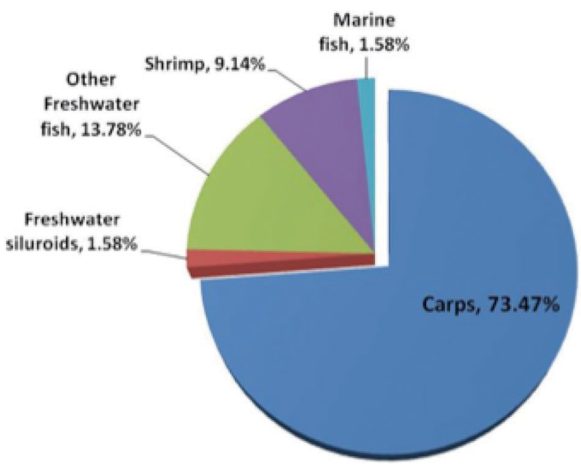
Country case study 2 Assessment report on AMU and AMR risk in aquaculture in India

Gaurav Rathore
Fish Health Management & Exotics Division
ICAR-National Bureau of Fish Genetic Resources, Lucknow, India

Introduction

India is the second largest fish-producing country in the world with production of 11.41 million tonnes (MT) in 2016/2017 – 7.77 MT from the inland fishery sector and 3.64 MT from the marine fishery sector. Aquaculture production constituted 5.7 MT. Total production is expected to exceed 12.50 MT in 2017/2018 (NFDB, 2018). The export earnings from the fisheries sector were USD 5.8 billion in 2016/2017. The sector contributes about 0.92 percent of the national Gross Value Added (GVA) and over 5.23 percent to the agricultural GVA. It employs over 14.5 million people. The Ministry of Agriculture & Farmers Welfare has prepared the National Fisheries Action Plan (NFAP) to 2020 to enhance fish production and productivity and to participate in the Blue Revolution. The goal is to enhance fish production from 11.41 MT in 2016/2017 to approximately 15 MT by 2020.

Figure 1. Commodity-wise aquaculture production of India in 2016 (percent)



Source: FAO., 2018. Fisheries and aquaculture software. FishStatJ - Software for Fishery and Aquaculture Statistical Time Series. In: FAO Fisheries and Aquaculture Department [online]. Rome. http://www.fao.org/fishery/statistics/software/fishstatj/en.

Freshwater finfish aquaculture: In 2016, the share of inland fisheries and aquaculture was nearly 89 percent of total aquaculture production. Freshwater aquaculture showed an overwhelming ten-fold growth from 0.37 MT in 1980 to 5.0 MT in 2016. Freshwater aquaculture contributes to over 89 percent of the total aquaculture production (Figure 1). Species comprise Indian major carps, Chinese carps, catfishes (mainly pangasius), tilapia and freshwater prawns.

Indian carps culture: The three Indian major carps – catla (Catla catla), rohu (Labeor rohita) and mrigal (Cirrhinus mrigala) – contribute the bulk of production (3.79 MT) or 74 percent of the total freshwater fish production, followed by silver carp (Hypophthalmichthys molitrix), grass carp (Ctenopharyngodon idella) and common carp (Cyprinus carpio) (0.4 MT or 8 percent). The national mean production level from freshwater aquaculture ponds is about 3 000 kg/ha/year. Three types of culture systems predominate depending on varying levels of inputs and outputs they are categorized as low-, medium- and high-input systems.

- Low-input system: This is a fertilizer-based system where organic and inorganic fertilizers are major inputs besides stocking of carp seeds at low stocking densities. Fish production of around 2 tonnes/ha/year to 3 tonnes/ha/year is achieved without any supplementary feeding.
- Medium-input system: Similar to the low-input system, except supplementary feeding with oilcake and bran mixture (protein of 25 percent to 27 percent). Production levels of around 4 tonnes/ha/year to 8 tonnes/ha/year.
- High-input (intensive culture) system: Higher stocking density combined with higher feed inputs. Water exchange and aeration help in reducing metabolite loads from ponds. Production levels of around 10 tonnes/ha/year to 12 tonnes/ha/year. It also involves water quality monitoring and health management.

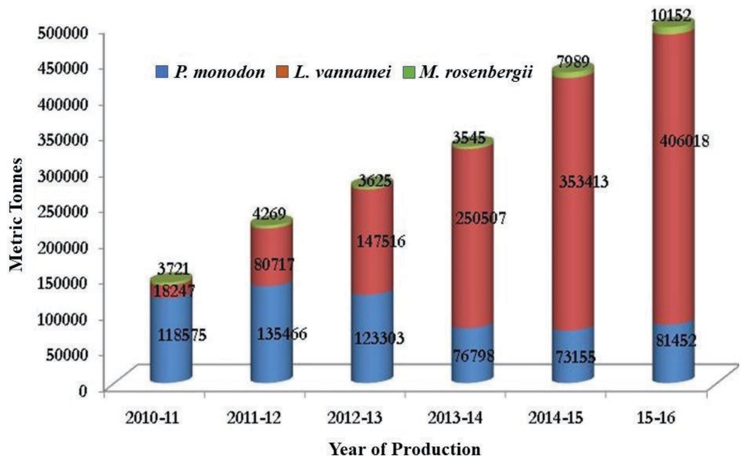
Catfish and tilapia culture: Catfishes and tilapia form a second important group contributing to aquaculture production in India. Cage culture of the exotic, Pangasiodon hypophthalmus, has gained wide acceptance in India. The State of Jharkhand has taken the lead in terms of installing about 3 000 cages in various reservoirs within the last three years owing to very high rates of production exceeding 50 kg/m^2 or approximately 500 tonnes/ha. Similarly, the culture of tilapia, Oreochromis niloticus, is also gaining importance in freshwater aquaculture.

Culture of freshwater giant prawn, Macrobrachium rosenbergii: In 2015/2016, total freshwater giant prawn production from nine maritime states was 10 152 tonnes from 12 704 ha with average productivity of 0.80 tonnes/ha/year. West Bengal was the leading producer followed by Odisha and Andhra Pradesh.

Brackishwater finfish culture: Asian seabass (Lates calcarifer), milkfish (Chanos chanos), pearlspot (Etropluss uratensis) and cobia (Rachycentron canadum) are important fish species for brackishwater fish farming in India. Brackishwater culture also includes farming of crustaceans, mainly shrimps, including P. monodon and L. vannamei (Figure 2). In 2015/2016, a total of 68 846 ha were under black tiger shrimp (P. monodon) culture in nine maritime states producing 81 452 tonnes with average production of 1.18 tonnes/ha/year. The State of Gujarat recorded maximum productivity of 3.12 tonnes/ha/year followed by Tamil Nadu and Odisha with productivity of 2.70 tonnes/ha/year and 2.02 tonnes/ha/year, respectively.

In 2015/2016, 59 116 ha were under whiteleg shrimp (L. vannamei) culture in nine maritime states producing 406 018 tonnes with Andhra Pradesh leading in the total area under culture and production. All India average productivity was 6.87 tonnes/ha/year.

Figure 2. Aquaculture production of shrimp and freshwater prawn from India



Source: FAO., 2018. Fisheries and aquaculture software. FishStatJ - Software for Fishery and Aquaculture Statistical Time Series. In: FAO Fisheries and Aquaculture Department [online]. Rome. http://www.fao.org/fishery/statistics/software/fishstatj/en.

Mariculture: Potentially 3 000 tonnes to 5 000 tonnes of fish are expected to be produced from 1 000 cages *per annum* in the next three years. It is anticipated that 35 percent of the cages will be stocked with cobia *(Rachycentron canadum),* 35 percent with sea bass *(Lates calcarifer),* 10 percent with snappers *(Lutjanus sp.)*/groupers *(Epinephelus sp.)*/lobsters, 10 percent with mullets *(Mugil cephalus)* and 10 percent with silver pompano *(Trachinotus blochii).* By adopting culture of these high-value species, production of 3 tonnes/cage to 5 tonnes/cage can be attained over six to nine months.

Cold water aquaculture: Presently, there are 62 rainbow trout farms with 369 raceways and 32 trout hatcheries with production capacity of 13 million eyed ova besides 625 trout units in the private sector.

Major disease issues

Freshwater finfish: The major pathogens reported from India in finfish are:

- Viral pathogens – cyprinid herpesvirus-2 (CyHv-2), carp edema virus (CEV), iridoviruses and tilapia lake virus (TiLV);
- Oomycetes – Aphanomyces invadans, Saprolegnia parasitica, S. ferax, S. diclina;
- Bacterial pathogens – Aeromonas hydrophila, A. veronii, A. sobria, Flavobacterium columare, Edwardsiella tarda, Acinetobacter baumannii, Photobacterium damselae, Pseumonas fluorescens, Citrobacter freundii, Klebsiella pneumniae; and
- Parasites – Myxobolus sp., Thelohanellus sp., Trichodina sp. Argulus sp., Lernaea sp., Dactylogyrus sp., Diplostomum sp.

Freshwater prawns: Infection with the Macrobrachium rosenbergii nodavirus commonly known as white tail disease (WTD). The disease occurs in larvae, postlarvae and early juveniles.

Brackishwater finfish: Viral nervous necrosis (VNN) is a major disease problem in larval and juvenile stages of brackishwater finfish. The prevalence of VNN is reported to be 40 percent in farmed fish. Iridoviruses are also emerging as major pathogens in cultured finfish such as seabass, wild mullet, wild red snapper, tilapia, cobia and pompano from various locations in Tamil Nadu and Andhra Pradesh. The prevalence of iridoviruses is nearly 20 percent in cultured fishes.

Crustaceans/shrimps: The major infectious diseases reported in shrimp farms are white spot disease (WSD; 8.9 percent), hepatopancreatic microsporidiosis caused by Enterocytozoon hepatopenaei (EHP; 23.6 percent) and infectious hypodermal and haematopoietic necrosis (IHHN; 1.3 percent). Other syndromes due to poor farm management are stunted growth (15.17 percent), white faeces syndrome (16.5 percent), white muscle syndrome (3.4 percent), chronic mortality syndrome (2.7 percent) and black gill syndrome (7.5 percent). Vibriosis caused by Vibrio harveyi and V. campbelli affect early postlarval stages of peaneid shrimps in India.

Marine fish: Viral nervous necrosis virus (NNV) infection in cage-cultured sea bass; vibriosis infection in cage farms with V. alginolyticus and V. harveyi. Infection with Photobacterium damselae ssp. damselae is also reported.

Regarding parasites, myxosporeans, *Ceratomyxa collarae* n. sp. and *Ceratomyxa leucosternoni* n. sp. are reported in marine ornamentals. The acanthocephalan *Filisoma keralensis* n. sp. infects the intestines of *Scatophagus argus.* Others include the dinoflagellate *Amyloodinium ocellatum* and the monogenean Diplectanum *latesi* and the crustacean isopod *Cirolana fluviatilis* in seabass.

Infections with *Perkinsus beihaiensis* and *P. olseni* occur in the farmed bivalves *Perna viridis* and Indian edible oyster *Crassostrea madrasensis.*

Cold water fisheries: The bacterial pathogens *Lactococcus garvieae* and *Aeromonas* sp. have been reported in rainbow trout, while *Chryseobacterium scophthalmum* and *Pseudomonas koreensis* have affected golden mahseer.

Agencies responsible for regulation and monitoring of AMU and AMR in aquaculture

The main agencies involved in the regulation and monitoring of AMU and AMR in aquaculture in India are described hereunder.

The Ministry of Agriculture and Farmer's Welfare (MOAFW): Two departments under the ministry address the development and growth of fisheries and aquaculture:

(1) The Department of Animal Husbandry, Dairying and Fisheries (DAHDF): The DAHDF is the apex department under the MOAFW and is responsible for matters related to fish production and fisheries. Under the administrative control of the DAHDF, there are two autonomous organizations related to aquaculture:
(2) The National Fisheries Development Board (NFDB). The NFDB was established in 2006 to enhance fish production and productivity in the country and to coordinate fishery development in an integrated and holistic manner. The main aim of the NFDB is to realize the untapped potential of the fisheries sector in inland and marine capture, culture, processing and marketing of fish, and overall growth of the fisheries sector with the application of modern research and development tools.

The Coastal Aquaculture Authority (CAA): This was established under the Coastal Aquaculture Authority Act, 2005. The main objective is to regulate coastal aquaculture activities to ensure sustainable development without causing damage to the coastal environment. The CAA can issue regulations for the construction and operation of aquaculture farms in coastal areas, inspection of farms to ascertain their environmental impact, registration of aquaculture farms, standards for inputs and effluents, and removal or demolition of coastal aquaculture farms that cause pollution. One of the major tasks accomplished by the CAA has been the registration of shrimp farms. The CAA also provides guidelines on registration of hatcheries, MRLs in shrimp, standards for probiotics and feed, identification of high tide line and intertidal areas, environmental impact assessment and stocking density. Some of the key decisions related to shrimp health management, including AMU and AMR are:

Registration of farms: A total of 34 784 farms are registered (mandatory) with the CAA with a total farm area of 55 273 ha for shrimp culture nationwide.

Registration of hatcheries: A total of 297 hatcheries and 37 nauplii rearing centres with production capacity of 32 827 million seeds are currently registered with the CAA for L. vannamei. During 2017, 230 881 broodstocks were imported for seed production.

Registration of farm inputs: The CAA had registered 1 744 farm inputs from 217 manufacturers by July 2018 under eight categories for use in aquaculture. They included 748 feed additives (42.89 percent), 425 probiotics (24.37 percent), 241 chemicals (13.82 percent), 144 disinfectants (8.26 percent), 49 immunostimulants (2.81 percent), 62 larval feeds (3.56 percent) and 75 grow-out feeds (4.30 percent). All the registered products were labelled as antibiotic-free. The CAA stipulates that shrimp hatchery operators and farmers can only use registered antibiotic-free aquaculture inputs in their hatcheries and farms.

Guidelines for regulating coastal aquaculture: These target environmentally responsible and socially acceptable coastal aquaculture and the positive contributions that shrimp farming and other forms of aquaculture can make to poverty alleviation in coastal areas. They are also intended to assist farmers in adopting good management practices.

Use of antibiotics/drugs: The 20 antibiotics/pharmacologically active substances presently banned for use in shrimp culture are: 1) chloramphenicol; 2) nitrofurans including furaltadone, furazolidone, furylfuramide, nifuratel, nifuroxime, nifurprazine, nitrofurantoin, nitrofurazone; 3) neomycin; 4) nalidixic acid; 5) sulphamethoxazole; 6) Aristolochia spp. and preparations thereof; 7) chloroform; 8) chlorpromazine; 9) colchicine; 10) dapsone; 11) dimetridazole; 12) metronidazole; 13) ronidazole; 14) ipronidazole; 15) other nitroimidazoles; 16) clenbuterol; 17) diethylstilbestrol (DES); 18) sulphonamide drugs (except approved sulphadimethoxine, sulphabromomethazine and sulphaethoxypyridazine); 19) fluroquinolones; and 20) glycopeptides.

The Department of Agriculture Research and Education (DARE): The Indian Council of Agricultural Research (ICAR) is an autonomous organization working under the administrative control of DARE, MOAFW for agricultural development, including the fisheries sector.

ICAR is the apex body for coordinating, guiding and managing research and education in agriculture under eight divisions (crop science, horticulture, natural resource management, agricultural engineering, animal sciences, fisheries, agricultural education and agricultural extension). ICAR has 101 research institutes including eight fisheries institutes: the National Bureau of Fish Genetic Resources (NBFGR), Central Institute of Fisheries Education (CIFE), Central Institute of Marine Fisheries Research Institute (CIMFRI), Central Institute of Brackishwater Aquaculture (CIBA), Central Institute of Freshwater Aquaculture, (CIFA), Central Inland Fisheries Research Institute (CIFRI), Central Institute of Fisheries Technology (CIFT) and Directorate of Coldwater Fisheries (DCFR). With respect to work on AMU and AMR in aquaculture, ICAR fisheries research institutes are working on developing new technologies for sustainable aquaculture including research on health management, surveillance of pathogens, best management practices, biosecurity and prevention and control of infection. Specifically for AMR, ICAR in collaboration with FAO held a series of seminars on the establishment of a national network of fisheries and veterinary laboratories to strengthen surveillance of AMR in India. The network is called the Indian Network for Fishery and Animal Antimicrobial Resistance (INFAAR). Subsequently, the network programme on AMR in fisheries was launched in 2018, with all eight ICAR fisheries institutes as partners and the NBFGR as the nodal centre.

Ministry of Commerce and Industry: The Department of Commerce under the ministry is mandated to regulate, develop and promote India's international trade and commerce through appropriate international trade and commercial policy as well as implementation. Under the administrative control of the DAHDF, there are two autonomous organizations related to aquaculture: the Export Inspection Council (EIC) and Marine Products Export Development Authority (MPEDA).

The EIC is the official export certification body that ensures the quality and safety of products exported from India. With respect to AMU, the MPEDA was designated to carry out residue monitoring on behalf of the EIC in all aquaculture farms, processing establishments, feed mills and hatcheries linked to export production of aquaculture products. This included overall monitoring of aquaculture products at all stages of production. The scheme is known as the National Residue Control Plan (NRCP). Under the NRCP, residues of veterinary medicinal products including antibiotics, other drugs, growth promoters, dyes and environmental contaminants are monitored.

The MPEDA was established in 1972 and given the mandate to promote marine products with special reference to exports. The MPEDA regulates exports of marine products and ensures sustained, quality seafood exports from the country. The MPEDA is empowered to carry out inspection of marine products, training as well as marketing of the seafood overseas. Based on recommendations from the MPEDA, the government issues new standards for fishing vessels, storage premises, processing plants and conveyances. The MPEDA also regulates aquaculture production and operates the NRCP for aquaculture products in India.

Ministry of Health and Family Welfare

The Food Safety and Standards Authority of India (FSSAI) was established under the Food Safety and Standards Act, 2006 and functions under the administrative control of the Ministry of Health and Family Welfare. The FSSAI sets standards for food and to regulate manufacturing, storage, distribution, sale and import to ensure the availability of safe and wholesome food for human consumption. Under the Food Safety and Standards Act, 2006, antibiotics in seafood including shrimps, prawns or any other variety of fish and fishery products, shall not exceed the maximum limits (tetracycline and oxytetracycline, 0.1 ppm; trimethoprim; 0.05 ppm; and oxolinic acid, 0.3 ppm). In addition the use of any of the following antibiotics and other pharmacologically active substances shall be prohibited in any unit processing seafood including shrimps, prawns or any other variety of fish and fishery products:

- All nitrofurans including (a) furaltadone, (b) furazolidone, (c) furylfuramide, (d) nifuratel, (e) nifuroxime, (f) nifurprazine, (g) nitrofurantoin, (h) nitrofurazone;
- Chloramphenicol;
- Neomycin;
- Nalidixic acid;
- Sulphamethoxazole;
- Aristolochia spp. and preparations;
- Chloroform;
- Chloropromazine;
- Cholchicine;
- Dapsone;
- Dimetridazole; and
- Metronidazole.

The import, manufacture, distribution and sale of drugs, cosmetics and medical devices in India is regulated under the provisions of the Drugs and Cosmetics Act, 1940 and the Drugs and Cosmetics Rules, 1945. The Central Government exercises regulatory control over these articles imported into the country through the Central Drugs Standard Control Organization (CDSCO) headed by the Drugs Controller General (India) (DCGI). Under the Drug and Cosmetics Act, the regulations for the manufacture, sale and distribution of drugs are primarily the concern of the state authorities while the central authorities are responsible for the approval of new drugs, clinical trials in the country, setting standards for drugs, control over the quality of imported drugs, coordination of state drug control organizations and providing expert advice. The DCGI is responsible for the approval of licences of specified categories of drugs such as blood and blood products, I.V. fluids, vaccine and sera.

Use of antimicrobials in aquaculture

An ICAR-funded 'All India Network Project on Fish Health' has been operational since 2015 in all of the eight ICAR fisheries research institutes across the country, coordinated by CIBA, Chennai. Under this project, information on different types of drugs available in the Indian market were collected and analysed. According to CIBA's annual report for 2016/2017, information on 1 300 drugs and chemicals was collected from aquaculture markets throughout the country. These were classified into seven categories: disinfectants/sanitizers (13 percent); soil and water conditioners (35 percent); nutritional supplements/feed additives (29 percent); probiotics and immunostimulants (15 percent); antibiotics/antimicrobials (3 percent); antiparasitics/insecticides (4 percent); and hormones/spawning aids (1 percent).

The drugs listed hereunder may not represent the true/complete picture of use in Indian aquaculture. Use of selected antibiotics in Indian aquaculture is banned presently, even though antibiotics were in use historically.

Antiparasitics

- Formalin (prolonged immersion, 25 ppm) is used for treatment of ich disease in finfish; 10 ppm to 20 ppm in shrimp hatcheries for control of protozoans;
- Salt solution (2.5 percent) is used against various unicellular parasites in short-term bath treatment;
- Organophosphate is used for treatment of Lernea, anchor worm and Argulus infestations;
- Diflubenzuron (0.025 ppm to 0.05 ppm) for treatment of Argulus infestation;
- Copper sulphate is used as a herbicide, moluscicide and for treatment of external protozoa and fungi; and
- Malachite green is used at a concentration of 0.01 ppm to 0.02 ppm for 24 hours to 48 hours in tanks for ich disease in finfish; 0.075 ppm in shrimp hatcheries for control of protozoans and larval mycosis.

Antibacterial drugs/chemicals

- Potassium permanganate at 2 ppm for bacterial diseases;
- Methylene blue at 50 ppm to 75 ppm in short-term bath treatment;
- Furazolidone/nitrofurazone at 20 ppm in short-term and 2 ppm in long-term bath treatment for control of Vibrio in hatcheries;
- Sulphonamides in combination with trimethoprim;
- Oxytetracycline at 50 ppm to 75 ppm in feed in finfish and 10 ppm as bath treatment in shrimp hatcheries;
- Chloramphenicol at 10 ppm as bath treatment in shrimp hatcheries;
- Neomycin at 10 ppm as bath treatment in shrimp hatcheries; and
- Erythromycin at 2 ppm as bath treatment in hatcheries.

Target animals and farming systems

Low frequency usage: Freshwater aquaculture contributes to over 89 percent of total aquaculture production. Freshwater finfish culture is mainly carp-centric and most aquaculture is generally medium-input aquaculture. This type of culture system involves supplementary feeding. Disease problems are minimal and therefore the use of aquaculture medicines is insignificant. However, with the introduction of pangasius and tilapia farming in ponds and cages, there has been a shift from medium- to high-input farming. Disease problems become more apparent compared to the medium-input culture system and are generally due to poor water quality or poor quality of seeds. Farmers generally resort to disinfectants and sanitizers or soil and water conditioners for health management of fish during grow-out. Commercial feeds which are certified as antibiotic free are used. Thus, it is assumed that the use of antimicrobials/antibiotics in freshwater finfish culture is very limited.

Medium frequency usage: The shrimp aquaculture industry is mostly export oriented. The industry is governed by the tough regulations of importing countries, especially on antibiotic residues. Regular monitoring of the shrimp farms under the NRCP also ensures very high compliance with nonusage of antibiotics in the grow-out system. NRCP data indicated that 7 302 shrimp samples from farms were tested for A6 compounds. Of these, 429 samples were noncompliant (6.24 percent). Similarly, 7 357 shrimp samples from farms were tested for B1 compounds. Of these only five samples were noncompliant. With the introduction of L. vannamei in Indian aquaculture, the intensification of culture practices has increased. As a result, infection with the white spot syndrome virus (WSSV) and EHP are the most common problems. Farmers have adopted better management practices including use of seeds from specific pathogen free (SPF) stock, polymerase chain reaction (PCR)-based screening of seeds for pathogens, water quality monitoring and optimum feeding for minimizing disease risks. Application of disinfectants and sanitizers or soil and water conditioners, probiotics and use of plant-based extracts such as garlic, molasses/jaggery are common for managing disease problems. Use of antibiotics in grow-out shrimp culture systems is less common to minimize the risk of rejection of samples during NRCP testing by the MPEDA.

High frequency usage: The use of antibiotics appears to be on the higher side in shrimp hatcheries for higher survival of PL/larvae. As evident from NRCP data, the use of nitrofuran/chloramphenicol is quite widespread. Of the 946 seed samples tested for A6 compounds during the last five years, 569 samples tested negative while 377 samples (39.8 percent) were found to be noncompliant. The antibiotics used in hatcheries are in high concentrations so the residue persists in the shrimps even during the grow-out period. As a result, grow-out samples also occasionally test positive for A6 compounds. In contrast, use of B1 compounds i.e quinolones, tetracyclines and sulphonamides is almost negligible in shrimp hatcheries and grow-out culture systems.

Methodologies: The two most common routes of administration for antimicrobials in aquaculture are immersion therapy and medicated feed.

There are generally two types of immersion therapy:

Dip treatment is commonly used for problems involving ectoparasites and to treat bacterial diseases among juvenile fish. It is also common in the aquarium trade especially with chemicals such as potassium permanganate, methylene blue and so forth. Antibiotic baths are mainly used for marine finfish and crustacean hatcheries. They usually last for one to two hours.

Prolonged bath treatment is a common method for applying disinfectants and chemicals in freshwater ponds and cultured shrimps, mostly to improve water quality parameters.

Oral therapy is generally followed for administering feed additives/probiotics/immunostimulants or antibiotics in the feed. The successful administration of a medicated feed is largely dependent on the level of feeding of the infected population. Most sick fish tend to cease feeding, while palatability also becomes an issue with certain formulations. Correctly diagnosing a disease outbreak at an early stage and offering a palatable feed are therefore important.

Estimated quantity (range by species and farming systems) and estimated cost per unit of aquaculture area per year

The Indian pharmaceutical industry was estimated to be worth about USD 27 billion in 2016/2017 (see https://www.ibef.org) with approximately 6 000 to 8 000 production facilities operating in the country. Indian pharmaceutical companies can be broadly classified as active pharmaceutical ingredient (API) manufacturers and formulation companies. API manufacturers produce antibiotics in bulk and then sell the formulation to other companies to produce finished products like powders, tablets and vials.

In India, there are at least 40 antibiotic API manufacturers and at least 250 antibiotic formulation companies for human use. There are nearly 188 companies manufacturing antibiotics for animal usage. However, there are no figures for products, production and sales. In the absence of any authentic data, the government often fails to monitor compliance and enforce laws, and many unapproved products continue to fill the market.

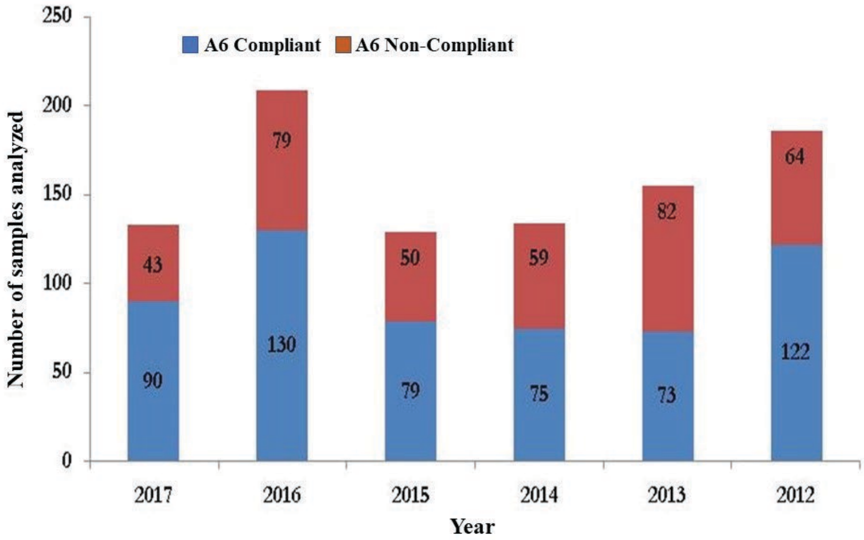
The Union Health Ministry has made it mandatory for companies to disclose, inter alia, detailed information about their operations, products, production and sales since July 2018. The Health Ministry has proposed changes through a Gazette notification to the Drugs and Cosmetics Rules, 1945 to make this provision mandatory. The pharmaceutical companies have to submit these details to the DCGI within three months. Enforcement of the notification provides accurate data on AMU in India.

In 2010, it was estimated that India was the fifth largest consumer of antibiotics in food animals (poultry, pigs and cattle), and with rising incomes and changing dietary patterns leading to an increase in the demand for animal protein, especially for poultry, antibiotic use is projected to grow by 312 percent; this will make India the fourth-largest consumer of antibiotics in food animals by 2030 (Van Boeckel et al., 2015). At present (July 2018), there are 217 pharmaceutical and feed companies registered at the CAA for production and supply of antibiotic-free inputs in aquaculture in India (Gandra et al., 2017).

Actual data on AMU in aquaculture are not available. Detecting the presence of antibiotic residues in aquatic animals and their metabolites is an indirect method of actual usage of antibiotics in aquaculture. The MPEDA undertook sampling and testing of shrimp farms, freshwater prawns, finfish, feed mills and shrimp seeds from hatcheries for detection of antibiotic residues under two categories: A6 compounds – chloramphenicol and nitrofuran metabolites; and B1 compounds – quinolones, tetracyclines and sulphonamides. This was an activity under the NRCP of the Export Inspection Council. Results of the last six years (2012 to 2017) indicated that a total of 7 302 shrimp samples from farms were tested for A6 compounds (Figure 3), of which 429 samples were noncompliant (6.24 percent). Similarly, a total of 7 357 shrimp samples from farms were tested for B1 compounds (Figure 5), and only five samples were noncompliant (0.07 percent). Shrimp seeds from hatcheries were also tested for A6 compounds (Figure 4). Of the 946 samples tested, 569 samples tested negative, while 377 out of 946 samples (39.8 percent) were noncompliant for A6 compounds. A total of 188 shrimp seed samples were tested for B1 compounds and only one sample was noncompliant (0.53 percent).

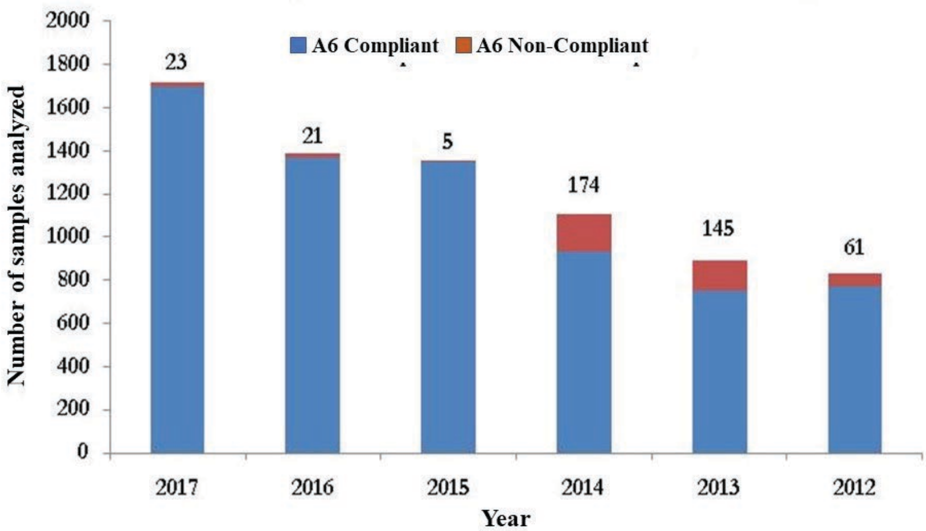
The analysed data showed very low usage of antimicrobial compounds in Indian aquaculture except for shrimp hatcheries.
Follow-up action on noncompliant samples: A joint inspection of farms was conducted by the EIC and MPEDA to trace the origin of contamination and a follow-up sample collection was done for further analysis. If the sample tested positive again, a showcase notice was issued to the defaulters. Appropriate guidelines and actions were suggested based on the replies and noncompliant facilities were subjected to stringent checks for the next 12 months.

Figure 3. Year-wise detection of chloramphenicol/nitrofuran metabolites (A6 compounds) in shrimp from shrimp farms under the NRCP



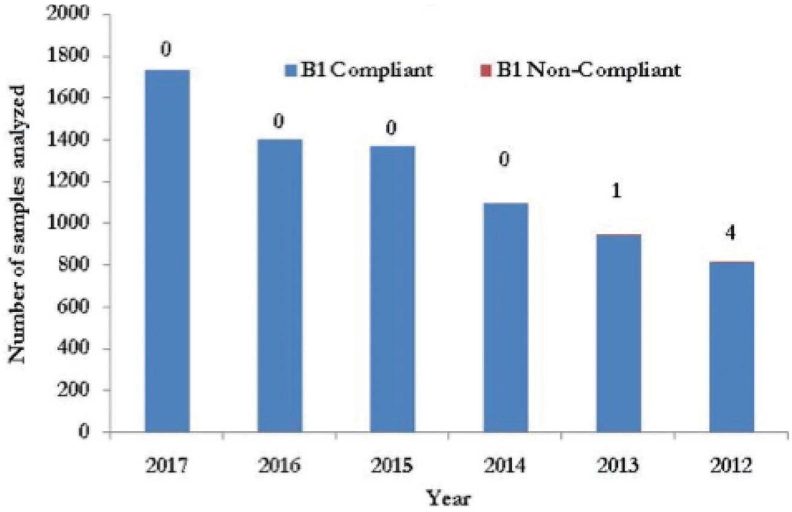
Source: National Residue Control Plan (NRCP) of the Export Inspection Council, India.

Figure 4. Year-wise detection of chloramphenicol/nitrofuran metabolites (A6 compounds) in shrimp seed from shrimp hatcheries under the NRCP



Source: National Residue Control Plan (NRCP) of the Export Inspection Council, India.

Figure 5. Year-wise detection of quinolones/tetracyclines/sulphonamides (B1 compounds) in shrimp from shrimp farms under the NRCP



Source: National Residue Control Plan (NRCP) of the Export Inspection Council, India.

Testing of antibiotic residues in Indian shrimp by importers

Export of Indian shrimps to the United States in 2015 amounted to 135 352 tonnes in 6 800 containers of 18 tonnes to 20 tonnes each. This accounted for 23.10 percent of total shrimp imports to the United States. Out of 6 800 containers, detection of antibiotic residues was reported in 34 consignments only (0.5 percent). This indicates that the use of antimicrobials in Indian shrimp aquaculture for exports is extremely limited (Ravisankar and Vinoth, 2016).

Potential AMR risks related to aquaculture (human, animal and environmental)

In 2014, India was the highest consumer of antibiotics, followed by the People's Republic of China and the United States. However, the per capita consumption of antibiotics in India is much lower than in several other high-income countries (Laxminarayan et al., 2016). Use of antibiotics in aquaculture has wide ramifications for human, animal and environmental health.

1. Risk of antibiotic residues in aquatic animal products meant for human consumption. Antibiotic residues can cause toxicity or allergic reactions in humans besides development of AMR in gut micro-organisms. Chloramphenicol can cause fatal aplastic anaemia and nitrofurans are classified as carcinogens.
2. Risk of antibiotic residues or metabolites in aquatic environments. It is estimated that most antibiotics administered to fish as medicated pelleted feed are released into the aquatic environment via urinary and faecal excretion and/or as unused

medicated food. These residues are potential environmental micropollutants which spread to aquatic ecosystems and become a source of artificial environmental stress for wild fish. The half-life of tetracycline in sediment is known to be nearly three months. These low levels of oxytetracycline can suppress immune functions in carps. Effluents from antibiotic manufacturing units contain a substantial amount of antibiotics, leading to contamination of rivers and lakes and serve as reservoir for AMR genes in the environment.

3. Risk of AMR development in micro-organisms and pathogens associated with aquatic animals. Resistant bacteria in the aquaculture environment can act as a reservoir of resistance genes from which genes can be further transferred and may ultimately end up in human pathogens. This can lead to treatment failures in humans. It is perceived that the antimicrobial residues in foods have a significantly lower human health risk than the risk related to AMR bacteria in food.

List of approved and banned antimicrobials in aquaculture

There is no list of approved antimicrobials for use in aquaculture. However, there is a list of 20 antibiotics/pharmacologically active substances that are presently banned for use in shrimp aquaculture: 1) chloramphenicol; 2) nitrofurans including furaltadone, furazolidone, furylfuramide, nifuratel, nifuroxime, nifurprazine, nitrofurantoin, nitrofurazone; 3) neomycin; 4) nalidixic acid; 5) sulphamethoxazole; 6) Aristolochias spp. and related preparations; 7) chloroform; 8) chlorpromazine; 9) colchicine; 10) dapsone; 11) dimetridazole; 12) metronidazole; 13) ronidazole; 14) ipronidazole; 15) other nitroimidazoles; 16) clenbuterol; 17) diethylstilbestrol; 18) sulphonamide drugs (except approved sulphadimethoxine, sulphabromomethazine and sulphaethoxypyridazine); 19) fluroquinolones; and 20) glycopeptides.

National action plan/strategy on AMU and AMR

In May 2015, the 68th World Health Assembly (WHA) endorsed the Global Action Plan on Antimicrobial Resistance (GAP-AMR) – including antibiotic resistance, the most urgent drug resistance trend. The WHA resolution urged member states to align their national action plans on AMR with the GAP-AMR by May 2017. Commitment by global leaders to combat AMR was further strengthened at the High-Level Meeting on AMR at the United Nations General Assembly on 21 September 2016. The Ministry of Health & Family Welfare issued three governance mechanisms in September 2016 to address this challenge. These include the Inter-sectoral Coordination Committee, the Technical Advisory Group and the Core Working Group on AMR for technical coordination and oversight.

The Core Working Group on AMR drafted the National Action Plan on Antimicrobial Resistance (NAP-AMR), which was further reviewed at the National Workshop on Development of the National Action Plan on AMR that included members from the Core Working Group and the Technical Advisory Group.

Six strategic priorities have been identified under the NAP-AMR:

1. Improving awareness and understanding of AMR through effective communication, education and training.
2. Strengthening knowledge and evidence through surveillance.
3. Reducing the incidence of infection through effective infection prevention and control.
4. Optimizing the use of antimicrobial agents in health, animals and food.
5. Promoting investments for AMR activities, research and innovations.
6. Strengthening India's leadership on AMR.

The National Health Policy, 2017 highlighted the problem of AMR and called for a rapid standardization of guidelines regarding antibiotic use, limiting the use of antibiotics as over-the-counter medications, banning or restricting the use of antibiotics as growth promoters in animal livestock and pharmaco-vigilance including prescription audits inclusive of antibiotic usage in hospitals and communities. The complete document is available at http://www.searo.who.int/india/topics/antimicrobial_resistance/nap_amr.pdf.

Other national regulations on the supply, sale and use of antimicrobials

The CDSCO issued an advisory on the 'Rational Use of Antibiotics for Limiting Antimicrobial Resistance' in 2017 to curb and control indiscriminate use of antibiotics. Such indiscriminate use may be due to easy availability of prescription drugs, injudicious use in hospitals as well as uncontrolled use in agriculture, animal husbandry and fisheries. The main features of the advisory related to agriculture are:

A separate Schedule H1 under the Drugs and Cosmetics Rules, 1945 was introduced in 2013 containing 46 drugs which included 24 third and fourth generation antibiotics, 11 antituberculosis drugs and 11 habit-forming drugs for stricter control over these products. Schedule H1 specifies that the drugs on this list must carry a prominent Rx symbol in red and a printed warning inside a box with red borders. Moreover, drugs included in Schedule H1 may be sold only with a prescription, and the pharmacist must maintain a separate register with the patient's name, contact details of the prescribing doctor, and the name and dispensed quantity of the drug.

The Drugs and Cosmetics Rules, 1945 were amended in 2012 for mandatory mention of the withdrawal period on the label of veterinary drugs used in livestock to ensure that the foodstuffs produced from the animals do not exceed the residual limit specified for them. The Ministry of Agriculture also issued a circular to directors/commissioners of animal husbandry in all states and union territories to advise state veterinarians, feed manufacturers and also persons involved in the treatment of animals about judicious use of antibiotics and hormones for the treatment of ailing food-producing animals.

State drugs regulators were notified in 2017 about enforcing strict compliance with the requirements of the Drugs and Cosmetics Act and Rules and also to raise awareness among the public about the adverse effects of misuse of antibiotics.

Issues, gaps and constraints in the implementation of regulations and plans/strategies for AMU and AMR

- Lack of awareness and understanding of AMR among stakeholders in human health, animal health and agriculture;
- AMR is not included as a core component in the professional education of medical, veterinary and aquaculture professionals;
- Lack of knowledge in the understanding of antibiotics, their indications and their appropriate usage;
- Prescription of antibiotics, especially for conditions like viral diseases or parasitic infestations for which antibiotic therapies are not recommended as the first line of approach;
- Financial incentives to prescribe antibiotics and the role of the pharmaceutical industry in encouraging prescription of antibiotics;
- Lack of financial and administrative commitment to prioritize AMR control programmes at the highest levels of national policy-making; and
- The limited laboratory-based AMR surveillance system for human health only.

Substandard drugs/spurious drugs: A survey of the extent of problems of 'Spurious and Not of Standard Quality Drugs ' was conducted by the National Institute of Biologicals, Noida, India from 2014 to 2016. The report found that the percentages of substandard and spurious drugs in the country were 3.16 percent and 0.0245 percent, respectively.

Monitoring and surveillance of AMU and AMR

Monitoring and surveillance of AMU in India by ICAR. ICAR's flagship programme 'All India Network Project on Fish Health' has been implemented since 2015 with ICAR-CIBA, Chennai as the lead institute in collaboration with nine other participating centres that cover states with major aquaculture activity. One of the major objectives of the programme is monitoring, profiling and studying drugs/chemicals usage in aquaculture freshwater, brackishwater and marine rearing systems through regular surveys. The information generated will be used to develop standards for the preparation of legal guidelines for the use of drugs/chemicals in aquaculture.

In response to World Health Organization's Global Action Plan on AMR, ICAR, in collaboration with FAO, organized a meeting at the National Agricultural Science Complex, New Delhi on 27 December 2016 chaired by ICAR's Director-General. This was followed by an FAO–ICAR meeting on the establishment of a national network of veterinary laboratories for AMR in Kolkotta from 7 to 8 March 2017. The meeting was attended by 32 participants representing both livestock and fishery sectors. USAID and

FAO experts moderated the meeting. The participants agreed to forge a national network of veterinary laboratories to strengthen surveillance of AMR in India called the 'Indian Network for Fishery and Animal Antimicrobial Resistance (INFAAR)'. A high-level Advisory Body shall be established by ICAR to guide all aspects of the network, review the data generated and have oversight on its operations. The Advisory Body shall meet at least twice a year and also undertake comprehensive review of network activities on an annual basis.

The network will undertake phenotyping characterization of priority pathogens and shall follow the same protocol for undertaking antimicrobial susceptibility testing. The Kolkatta meeting was followed by the FAO–ICAR meeting on 'Finalization of Operational Mechanisms for INFAAR' held at ICAR–CIFE, Mumbai on 14 July 2017. Subsequently, the Network Programme on AMR in Fisheries was launched on 24 March 2018, with all eight ICAR fisheries institutes as partners and ICAR–NBFGR as the nodal centre. The immediate objectives of the network programme are: (1) to establish baseline data on the prevalence of AMR micro-organisms and determinants; (2) to collect information on AMR trends in relevant micro-organisms. The focus is to identify AMR in aquatic animal pathogens and micro-organisms, including human pathogens, present on food derived from aquatic animals. The priority micro-organisms identified by the group were S. aureus, E. coli and Aeromonas spp. in freshwater aquaculture and S. aureus, E. coli and Vibrio spp. in brackishwater and marine aquaculture. Active surveillance for assessment of AMR will be carried out in food-producing healthy animals at farms/cages/reservoirs/wetlands/open waterbodies and food fish at markets. Trend analysis of the target pathogens will be done for at least two consecutive years.

Standard operating procedures for isolation, identification and antibiotic sensitivity testing of micro-organisms for the fisheries sector have been developed as part of the network programme. A field-based questionnaire for on-farm surveys will be used to help in establishing links between AMR data and actual use of antibiotics in culture practices. The analysis of the results will be done through WHONET software.

Strategy and actions in addressing AMR risks in aquaculture

The demand for enhancing food production is a major challenge so innovative sustainable aquaculture technologies are needed. However, as new technologies develop for increasing food production, the parallel increase of problems associated mainly with infectious diseases is inevitable. To counter the disease problem, antibiotics are used either as therapeutics or prophylactics. However, due to the issue of AMR in micro-organisms, there is a need to develop alternative therapies for preventing infectious diseases in aquaculture. Some of the alternative strategies to antibiotics being devised for Indian aquaculture are described hereunder.

Vaccination: An ideal method for preventing infectious diseases, but there are no commercially available vaccines against major diseases of finfish in India. A Consortia

Research Project on Development of Vaccines and Diagnostics in aquaculture funded by ICAR is working with the target of developing vaccines for important pathogens affecting cultured fish in India. The key pathogens targeted for developing vaccines are betanodavirus (infecting seabass), Edwardsiella tarda, Flavobacterium columnare and A. hydrophila for which a subunit vaccine using OMP-C & ABC transporter binding protein is being researched. For WSSV, development of an RNAi mediated prophylaxis and therapy are also being studied.

Phage therapy: Biocontrol of vibriosis using bacteriophages in shrimp hatcheries has been successful. One commercial product from Mangalore Biotech Laboratory, Luminil, is being marketed for biocontrol of luminous bacteria in shrimp hatcheries.

Development of probiotics and immunostimulants for shrimps: A total of 425 probiotics and 49 immunostimulant products are commercially available on the Indian market for application in aquaculture.

Surveillance of aquatic animal diseases: The National Surveillance Programme for Aquatic Animal Diseases is being implemented in 16 states through 24 collaborating institutes, with ICAR-NBFGR as the nodal centre. The programme aims to rapidly detect new and emerging pathogens, to know the occurrence and distribution of endemic pathogens, and improve disease reporting to international organizations. Under the programme, diagnostic capability for 29 OIE/NACA listed pathogens of regional importance has been developed and is being utilized for diagnosis as well as certification. PCR-based assays for diagnosis of emerging fish and shellfish pathogens are available in all ICAR fisheries research institutes and many state agricultural universities. Abdul Hakeem College, Vellore, Tamil Nadu is an OIE Reference Laboratory for WTD of freshwater prawns.

Safe introduction of exotics in the country: ICAR–NBFGR has prepared strategically important documents to guide the safe introduction of exotic aquatic species, which is implemented by the Department of Animal Husbandry, Dairying and Fisheries (DADF). The strategic guidelines comprise two documents – the 'National Strategic Plan for Aquatic Exotics and Quarantine' and the 'Aquatic Exotics and Quarantine Guidelines'. In addition, a document on management of fish genetic resources of India prepared by ICAR–NBFGR also includes guidelines for safe introduction of exotics. These documents provide a framework for minimizing the ecological and disease risks associated with the introduction of exotic aquatic animals. The documents have been guidelines for facilitating imports of exotic germplasm, mainly SPF broodstock of white leg shrimp (Litopenaeus vannamei) and tilapia. They contribute significantly in the production and export of fisheries products. According to the CAA, a total of 187 603 SPF broodstock of L. vannamei were imported during 2015/2016 for seed production after following quarantine certification. A total of 7 billion postlarvae were produced and supplied to registered shrimp farmers for safe aquaculture in the country.

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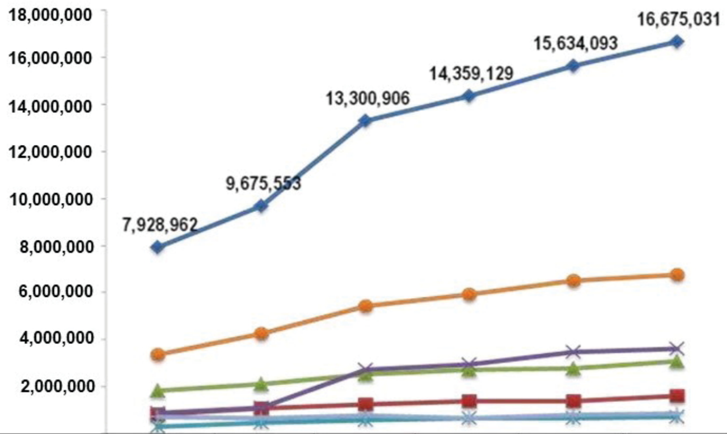
Country case study 3 Assessment report on AMU and AMR risk in aquaculture in Indonesia

Mukti Sri Hastuti and Siti Fatimah
Directorate General of Aquaculture, Ministry of Marine Affairs and Fisheries, Indonesia

Introduction

Aquaculture is very important for inhibiting stunting caused by malnutrition in Indonesia. In 2018, the prevalence of stunting was 37 percent (or one out of three children has a stunting problem). Fish provide healthy animal protein, have high nutritional content, are rich in omega-3 fatty acids, are relatively cheap and production is abundant. Aquaculture productions trend in Indonesia from 2011 to 2016 by area are shown in Figure 1.

Figure 1. Aquaculture production trends in Indonesia (tonnes) by area from 2011 to 2016



	2011	2012	2013	2014	2015	2016
NASIONAL	7,928,962	9,675,553	13,300,906	14,359,129	15,634,093	16,675,031
SUMATERA	845,459	1,077,198	1,262,870	1,396,839	1,392,244	1,605,115
J A W A	1,824,260	2,114,156	2,527,853	2,732,301	2,773,390	3,099,253
BALI-NUSA TENGGARA	880,180	1,104,590	2,730,396	2,959,973	3,479,149	3,623,631
KALIMANTAN	310,365	461,803	570,047	677,640	672,026	727,131
SULAWESI	3,354,454	4,249,427	5,431,890	5,913,751	6,498,839	6,764,482
MALUKU-PAPUA	714,245	668,378	777,850	678,625	818,446	855,418

Source: Directorate General of Aquaculture, 2018.

The main commodities cultured in Indonesia are shrimps *(Penaeus monodon, P. vannamei,* and *Macrobrachium rosenbergii),* finfish (milkfish *(Chanos chanos),* tilapia *(Oreochromis niloticus), Pangasius* sp., carp *(Cyprinus carpio),* gourami, catfish, groupers, seabass and pompano), molluscs and seaweeds *(Euchema/Kaphapaycus cottonii, Glacilaria* sp.). Aquaculture production in Indonesia by commodity, for the period 2011 to 2015, is shown in Table 1.

Table 1. Aquaculture production in Indonesia by commodity from 2011 to 2015

Commodity	Year				
	2011	**2012**	**2013**	**2014**	**2015**
Shrimp	401 154	415 703	638 955	639 369	615 871
Seaweed	5 170 201	6 514 854	9 310 874	10 076 992	11 269 342
Milkfish	467 449	518 939	627 333	631 125	672 196
Grouper	10 580	11 950	13 464	13 346	16 795
Seabass	5 236	6 198	6 735	5 447	6 558
Molluscs	48 449	19 472	29 091	44 394	43 304
Carp	332 206	374 366	412 703	434 653	461 546
Tilapia	567 078	695 063	914 778	999 695	1 084 281
Catfish	337 577	441 217	543 774	679 379	719 619
Pangasius	229 267	347 000	410 883	418 002	339 069
Gourami	64 252	84 681	94 605	118 776	113 407
Pompano				1 367	2 663
Others	287 460	231 769	285 800	296 586	289 442
Total	**7 928 962**	**9 675 553**	**13 300 906**	**14 359 129**	**15 634 093**

Source: Directorate General of Aquaculture.

Aquaculture systems commonly practised in Indonesia are floating nets (marine aquaculture), pond/tambak (brackishwater aquaculture) and ponds, floating nets, bamboo karamba, pen culture, rice fields (freshwater aquaculture). The area (hectares) and production data for each system in 2015 are shown in Table 2.

Disease is the major problem in aquaculture. Aquatic animal diseases of main concern in Indonesia based on Director General Decree No. 6/KEP-DJPB/2018 and to be used as a basis for annual disease surveillance and monitoring plan are summarized in Table 3.

Responsible agencies

The Directorate General of Aquaculture (DGA) under the Ministry of Marine Affairs and Fisheries (MMAF) is the agency responsible for regulation and monitoring of AMU and AMR in aquaculture. The organizational structure of the DGA is shown in Figure 2.

Table 2. Aquaculture systems in Indonesia in terms of area (hectares) and production (tonnes) in 2015

System	Area (ha)	Production (tonnes)
Mariculture	**285 527**	**10 174 022**
Seaweed	274 696	10 112 107
Floating nets	6 390	19 244
Others	4 441	42 671

System	Area (ha)	Production (tonnes)
Brackishwater (ponds)	**715 846**	**2 498 966**
Freshwater	**19 437 239**	**2 961 107**
Ponds	189 196	2 043 161
Cage culture	883	193 790
Floating nets	19 118 649	535 673
Pen culture	64	40 852
Rice/fish culture	128 447	147 631
Total	**20 438 612**	**15 634 095**

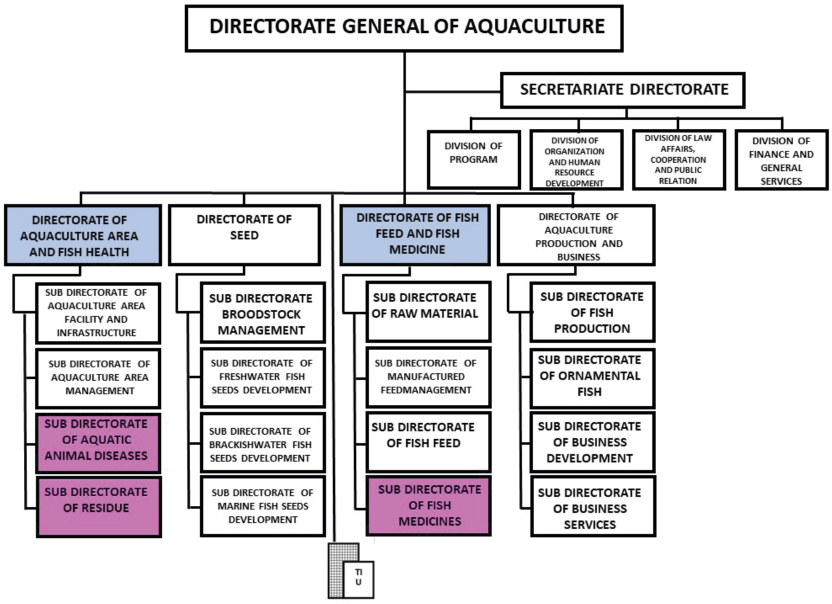
Source: Directorate General of Aquaculture.

Table 3. Major diseases in aquaculture in Indonesia

Disease	Disease agent	Susceptible species
Virus		
Koi herpes virus disease	Koi herpes virus	Common carp and Koi carp
Iridovirus disease, grouper iridoviral disease, sleepy grouper disease, lymphocystis disease	Iridovirus, lymphocystivirus, megalocytivirus (red sea bream iridovirus/RSIV, infectious spleen and kidney necrosis virus/ISKNV, dwarf gourami iridovirus/DGIV)	Tilapia, Asian seabass, groupers, and ornamental fish
Viral encephalopathy and retinopathy	Betanodavirus (Nodaviridae)	Seabass, and groupers
White spot disease	White spot syndrome virus (WSSV)	Black tiger shrimp and whiteleg shrimp
Infectious myonecrosis	IMNV	Whiteleg shrimp
White tail disease	Macrobrachium rosenbergii nodavirus (MrNV)	Freshwater prawn
Tilapia lake virus (TiLV)	Tilapia lake virus	Tilapia
Bacteria		
Streptococcosis	*Streptococcus agalactiae*	Tilapia, common carp and gourami
	Streptococcus iniae	Seabass
Enteric septicaemia of catfish (ESC)	*Edwardsiella ictaluri*	Pangasius, catfish
Motil aeromonas septicaemia (MAS)	*Aeromonas hydrophila*	Catfish, tilapia, common carp and gourami
Mycobacteriosis	*Mycobaterium fortuitum*	Gourami
Tenacebaculosis	*Tenacebaculum maritimum*	Seabass
White faeces syndrome	*Vibrio parahaemolythicus, Vibrio alginolyticus, Vibrio vulnificus*	Whiteleg shrimp
Ice-ice	*Pseudomonas* spp., *Pseudoalteromonas gracilis*, *Vibrio* spp.	Seaweed (E. cottonii)
Acute hepatopancreatic necrosis disease (AHPND)	Unique strain of Vibrio *parahaemolyticus*	Black tiger shrimp and whiteleg shrimp
Parasite		
Ichthyophthiriasis	*Ichthyophthirius multifilis*	Freshwater fish
Hepatopancreatic microsporidiosis	*Enterocytozoon hepatopenaei* (EHP)	Whiteleg shrimp

Source: DGA Decree No.6/2018.

Figure 2. Organizational structure of the DGA



Source: Directorate General of Aquaculture

There are two directorates (blue boxes) and three sub-directorates (pink boxes) under the DGA involved in AMR and AMU in aquaculture. The DGA also has close collaboration with the Marine and Fisheries Research Agency and other ministries including the Ministry of Health, Ministry of Agriculture and Ministry of Environment and Forestry that are instrumental in formulating the national action plan on AMR.

The Directorate of Aquaculture Area and Fish Health is responsible for aquatic animal medicine use and residue monitoring, while the Directorate of Fish Feed and Fish Medicine provides regulations on aquatic animal medicine registration, unit production certification and monitoring.

National regulations on AMU and AMR

There are no specific regulations governing AMU and AMR in aquaculture apart from the following regulations on fish medicines:

- Ministry of Marine Affairs and Fisheries (MMAF) Regulation No. 4/2012 Concerning Fish Medicines.
- MMAF Regulation No. 14/2013 Concerning Fish Medicines (Revised MMAF Regulation No. 4/2012).
- MMAF Regulation No. 24/2014 Concerning Good Manufacturing Practices of Fish Medicines.
- MMAF Decree No. 52/2014 Concerning Fish Medicines Classification (approved and banned).
- MMAF Regulation No. 39/2015 Concerning Residue Monitoring in Aquaculture.

National action plan/strategy on AMU and AMR

The Indonesian National Action Plan for Antimicrobial Resistance (NAP-AMR) was prepared by the Ministry of Health (as the lead agency) with the involvement of relevant ministries including the Ministry of Agriculture, the MMAF, the Ministry of Environment and Forestry, and the Ministry of Finance. The Indonesian NAP-AMR was endorsed by the World Health Organization in May 2017.

The strategies included under the NAP-AMR are:

- Improve awareness and understanding of AMR through effective communication, education and training;
- Strengthen knowledge through surveillance and research;
- Reduce incidence of infection with sanitation, hygiene and infection prevention measures;
- Optimize use of antimicrobial medicines for human and animal health; and
- Develop an economic case for sustainable investment and increase investment in new medicines, diagnostic tools, vaccines and other interventions.

List of approved and banned antimicrobials for aquaculture

Table 4 lists approved/recommended and banned antimicrobials for use in aquaculture. This is regulated by the MMAF Decree No 52/KEPMEN-KP/2014 concerning Fish Medicine Classification.

Antimicrobial use in aquaculture

Antimicrobial types: The most commonly used microbials in aquaculture are antibiotics. Fish farmers also occasionally use antifungal chemicals such as methylene blue. Based on fish/shrimp medicine monitoring from 2014 to 2016, Table 5 lists antibiotics that are commonly used in aquaculture. Antibiotics are used mainly to treat fish with clinical signs, or to control pathogenic agents in sick fish. Sometimes, antifungal agents are added to the holding water during fish transportation for disease prevention.

Table 4. Approved/recommended and banned antimicrobials for aquaculture

Group	Active substances
Approved/recommended:	
Tetracycline	Chlortetracycline, oxytetracycline, tetracycline
Macrolide	Erythromycin
Quinolone	Enrofloxacin
Anthelmenthics	Pyrantel pamoate, levamisole, praziquantel
Dyes	Methylene blue, basic bright green oxalate, acriflavine brilliant blue, tartrazin, Allura Red, Ponceau-4R, sunset yellow

Group	Active substances
Hormones	Gonadotrophin releasing hormone (GnRH), luteinizing hormone realizing hormone analogue (LHRHa), human chorionic gonadotrophin (HCG)
Vaccine	All vaccines for fish diseases in Indonesia
Banned	
Amphenicols	Thiamphenicol, chloramphenicol, florfenicol
Nitroimidazoles	Dimetridazole, metronidazole, fluconazole, tinidazole
Nitrofurans	Nitrofurantoin, nifurpirinol, furazolidone, nifurtoinol
Macrolides	Virginiamicyn, tylosin, spiramycin
Polypeptide	Zinc cacitracin
Others	Ranidazole, dapson, chlorpromazine, cholichicin

Source: Ministry of Marine Affairs and Fisheries Decree No. 52/2014.

Table 5. List of antibiotics used in aquaculture from 2015 to 2016

2014	2015	2016
Enrofloxacin	Enrofloxacin	Enrofloxacin
Amoxicillin	Oxy-tetracycline	Oxy-tetracycline
	Tetracycline	Ciprofloxacin
	Ciprofloxacin	Erythromycin
	Erythromycin	Streptomycin
	Streptomycin	Kanamycin
	Kanamycin	Tylosin
	Tylosin	
	Ampicillin	

Source: Directorate General of Aquaculture.

Aquaculture systems and species: Fish farmers tend to use antibiotics at the seed/fingerling production stage, when fish are still more susceptible to diseases. The use of antibiotics is also more common in intensive fish culture systems.

Although some antibiotics have been allowed for use in aquaculture, shrimp farmers who are members of the Shrimp Club of Indonesia have pledged not to use antibiotics throughout the culture process. This is to avoid rejection from the buyers/importing countries.

Drug administration: Antibiotics are commonly applied to affected aquatic animals by either of the following methods:

- Dipping/immersion (used by fish farmers to treat small fish/fish seeds); and
- Feed additives (antibiotics are added to fish feed to treat bigger fish during grow-out operations and for brood stock maintenance).

Estimated quantity and cost of antimicrobials: Fish farmers mostly use antibiotics for treating or controlling pathogenic agents using dosages advised by the drug companies, through information from other fish farmers or by following the instructions on the product labels. Thus, there is no concrete data available on the actual quantity and cost per unit of aquaculture.

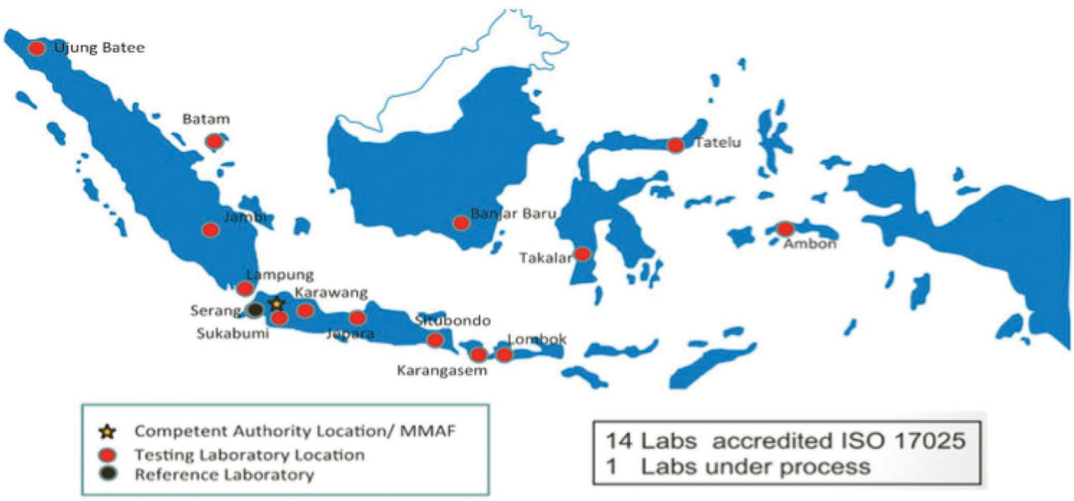
Potential AMR risks related to aquaculture (human, animal and environmental): The livestock industry uses a greater variety of approved antimicrobials compared to the aquaculture sector. There are some antimicrobials that are banned for use in aquaculture but approved for livestock. Moreover, the use and purchase of antibiotics for human and animal use without any prescription from a doctor or a veterinarian are considered to be sources of antimicrobial risk for aquaculture. The aquatic environment usually serves as a sink for all the sewage and wastewater from domestic and animal production units, which might end up as a water source for fish farming.

Monitoring and surveillance of AMU and AMR

After the Government of Indonesia promulgated a regulation allowing antibiotic use for aquaculture in 2014, the DGA began implementation of AMR monitoring in 2016. DGA Technical Implementing Units (DGA TIUs) are responsible for collecting bacterial samples and testing for AMR. There are 15 DGA TIUs distributed over 15 provinces (Figure 3).

AMR monitoring in 2016: AMR monitoring in 2016 focused on the antibiotics which are approved for use in aquaculture. Samples were taken from Aceh, Lampung, Banten, West Java, Central Java and East Java. The total number of bacterial isolates collected for AMR monitoring is summarized in Table 6.

Figure 3. Distribution of DGA TIU fish health laboratories



Source: Directorate General of Aquaculture.

Table 6. The number of bacterial isolates for AMR monitoring in 2016

Bacteria	Number of isolates for each antibiotic		
	Enrofloxacin (ENR)	Oxytetracycline (OTC)	Tetracycline (TE)
Aeromonas hydrophila	10	17	11
Vibrio sp.	30	23	10
Edwardsiella sp.	4	4	4
Total	44	44	25

Source: Directorate General of Aquaculture.

Results of the antimicrobial sensitivity test using the Kirby Bauer disc-diffusion method (qualitative) showed that A. hydrophila is most sensitive to ENR followed by OTC. OTC, on the other hand resulted in the most sensitive reaction for Edwardsiella sp. There is no effective antibiotic for Vibrio sp. The antibiotics that showed sensitivity results can be used for treatment of fish diseases caused by the tested bacteria. All the tested bacterial pathogens showed resistance to TE, which implied that it cannot be used for the treatment of the disease.

AMR monitoring in 2017: AMR monitoring was done by DGA TIUs in Batam, Lampung, Serang, Sukabumi, Karawang, Jepara, Situbondo and Mandiangin. The total number of isolates collected and tested for specific antibiotics (ENR, OTC and TE) is shown in Table 7.

Table 7. Total number of isolates challenged by specific antibiotics

Bacteria	Number of isolates for each antibiotic		
	ENR	OTC	TE
Aeromonas hydrophila	30	32	32
Vibrio sp.	49	48	13
Edwardsiella sp.	21	21	21
Total	100	101	66

Source: Directorate General of Aquaculture.

Based on the data on antibiotic sensitivity testing, there are no effective antibiotics for Vibrio sp. and Edwardsiella sp.; the percentage sensitivity for these bacteria was below 40 percent. A. hydrophila showed high sensitivity to TE, which totally contrasts with the result obtained in 2016, when it showed resistance to TE.

AMU survey in 2017: A survey on AMU was undertaken by the DGA's TIU (Marine Aquaculture Development Centre, Batam) supported by NACA in 2017. The survey was conducted in three provinces: Riau Island (four districts); Lampung (two districts); and

East Java (one district). The data were collected from grouper hatcheries (ten units) and nursery/grow-out cages (36 farms). Of the total hatchery farms surveyed, 60 percent used antimicrobials during production periods. The antibiotic use in grouper hatcheries was mostly (80 percent) under the supervision of veterinarian or aquatic animal health professionals. For nursery and grow-out cage farms, very low percentages were found for antimicrobial use during their culture operations, but most (66 percent) used antibiotics without supervision from veterinarians or aquatic animal health professionals. However, data showed that some farmers misused antibiotics by applying them to cultured fish without any disease indication, i.e. they used antibiotics as a preventive measure. Four antibiotics were used in grouper hatcheries and nursery/grow-out cages (ENR, OTC, erythromycin and cyprofloxacin), of which OTC was the most common (around 50 percent of total antibiotic usage).

AMR surveillance in 2018. The DGA conducted AMR surveillance in 2018 via TIUs for several cultured species (Table 8). The target bacterial pathogens included A. hydrophila (catfish), V. alginolyticus (grouper, seabass, pompano and milkfish) and V. parahaemolyticus (shrimps).

Based on the OIE Code, 134 strains of bacterial isolates were collected with design prevalence of 5 percent, sensitivity of 95 percent and specificity of 99 percent. AMR was analysed using AST and MIC.

Table 8. Target species under each of the TIUs involved in AMR surveillance

DGA's TIU	Species			
	Grouper	Shrimp	Catfish	Tilapia
BADC Ujung Batee	-	V	-	-
MADC Batam	V	-	-	-
FADC Jambi	-	-	V	V
MCMADC Lampung	V	-	-	-
CFDEI Serang	-	V	-	V
ABDC Karawang	-	V	V	-
MCFADC Sukabumi	-	-	V	V
MCBADC Jepara	-	V	-	-
BADC Situbondo	V	-	-	-
FADC Mandiangin	-	-	-	V
SBC Karangasem	-	V	V	-
MADC Lombok	V	-	-	-
FADC Tatelu	-	-	-	V
BADC Takalar	-	V	-	-
MADC Ambon	V	-	-	-

Source: Directorate General of Aquaculture.

Issues, gaps and constraints in the implementation of AMR action plans/regulations

The regulations and guidance supporting the implementation of AMR plans/strategies have yet to be completed. Thus, fish farmers still consider antibiotics as the most powerful tool to control fish diseases. No other alternatives are believed to rival antibiotics.

Strategy and actions in addressing AMR risks in aquaculture

Strategies and actions recommended for the overall management of AMR risk in aquaculture:

- Provide regulations and guidelines on AMR;
- Devise an AMR national action plan for aquatic animals/aquaculture;
- Raising public awareness;
- Implementation of Good Aquaculture Practices, 2nd version, based on the four pillars of sustainability:
    - ➢ food safety,
    - ➢ environmental responsibility,
    - ➢ social accountability, and
    - ➢ animal health and welfare.
- Adopt a national vaccination programme;
- Register antigens available for vaccination: A. hydrophila, Vibrio sp., Edwardsiella sp., Streptococcus iniae, Streptococcus agalactiae, KHV and iridovirus; and
- Under consideration for registration: VNN and Mycobacterium sp.

Country case study 4 Assessment report on AMU and AMR risk in aquaculture in Malaysia

Wan Norhana Md Noordin,[1] Rozana Johari[2] and Gerald Misol, Jr.[3]

[1]Fisheries Research Institute, 11960 Batu Maung, Penang, Malaysia
[2]Fisheries Biosecurity Laboratory, No. 82, Jalan Carruthers off Jalan Sultan Salahuddin, 50480 Kuala Lumpur, Malaysia
[3]Fisheries Biosecurity Division, Department of Fisheries Malaysia, Wisma Tani, Precinct 4, 62628 Putrajaya, Malaysia

Introduction

According to WHO, AMR occurs when micro-organisms (such as bacteria, fungi, viruses and parasites) change after they are exposed to antimicrobial drugs (such as antibiotics, antifungals, antivirals, antimalarials and antihelminthics). As a result, the medicines become ineffective and infections persist in the body, increasing the risk of spread to others. AMR is a serious and growing global public health threat. The intensification of animal production methods to cater to the demands of the increasing human population has been claimed to contribute to the AMR problem due to the increased use of antimicrobials in agriculture including aquaculture. In 2016, Malaysia established a National Antimicrobial Resistance Committee (NARC) comprising human and animal health sectors under the One Health initiative to develop the National Action Plan (NAP) on AMR. This was in accordance with the outcome of the 68th United Nations General Assembly in 2015 which urged all member states to adopt the global action plan on AMR and to develop national action plans on AMR. The initial NAP framework outlined the views of stakeholders from across the sectors of human and animal health (including fish) on status, gaps and solutions to address the AMR state of affairs in Malaysia. Since 2016, the Department of Fisheries (DOF) Malaysia has initiated plans and actions to evaluate AMU and AMR in aquaculture as well as to escalate awareness on AMR among farmers and competent authorities. This paper underlines all the activities concerning AMR in aquaculture carried out in Malaysia to assess the risk.

Background of aquaculture

Aquaculture is now being promoted in Malaysia as an important engine of growth and eventually to become the mainstay of the nation's economy. Similar to many countries in the region, aquaculture in Malaysia serves to provide supplementary fish for national food security and production of high-value fish for export. Situated in a region with an abundant supply of land and water, two determining factors for aquaculture activities, Malaysia has always strived to ensure that this sector is not sidelined in its development efforts.

According to the Fisheries Statistics (2016), a total of 21 939 fish farmers and aquaculturists were involved in the aquaculture industry. Most (72.5 percent) of the workforce was involved in freshwater aquaculture. The remaining 27.5 percent of fish farmers/aquaculturists was involved in brackishwater aquaculture. In 2016, freshwater aquaculture contributed 103 348.21 tonnes of production, valued at MYR 1 billion. The main cultured species were freshwater catfish (*Clarias* sp.), black and red tilapia (*Oreochromis* sp.), riverine catfish (*Pangasius* sp.) and freshwater giant prawn *(Macrobrachium rosenbergii)*. Brackishwater aquaculture production in 2016 contributed about 304 039 tonnes, valued at MYR 2 billion. The main cultured species were marine prawns *(Penaeus vannamei and Penaeus monodon)*, cockles *(Anadara granosa)*, grouper, red snapper and seabass.

According to the annual report of the Fisheries Biosecurity Division of the Department of Fisheries in 2016 (Department of Fisheries Malaysia, 2018), the common diseases for shrimp in Malaysia were WSSV, IHHNV and vibriosis. AHPND has occurred frequently in white shrimp since 2011 and was manifested in 2015 in tiger shrimp. Other new emerging diseases such as infectious myonecrosis virus (IMNV) and hepatopancreatic microsporidiosis caused by EHP have also been reported in white shrimp in Malaysia since 2014.

For finfish, the common diseases in Malaysia are viral infections especially viral nervous necrosis (VNN), iridoviruses and megalocytivirus. VNN is considered endemic to Malaysia for marine finfish (Zainathan et al., 2016). Bacterial infections are also frequently found in both marine and freshwater fish which occur as secondary infections in most disease outbreak cases. Common fish pathogens in Malaysia are Vibrio sp., Streptococcus sp. and Aeromonas sp. In 1996, Malaysia experienced notable disease outbreaks caused by Streptococcus agalactiae in tilapia (Oreochromis sp.) which resulted in mortality of more than 60 percent (Siti-Zahrah et al., 2008). Infections with Vibrio sp. are the most common in marine finfish.

Use of antimicrobials in aquaculture (past and present)

In Malaysia, published information on antimicrobial use, particularly antibiotics in aquaculture, is scarce. The most recent is the report on the use of chemicals in aquaculture in Malaysia by Shariff et al. (2000). According to the report, a wide variety of antimicrobials were used for treating fish and shrimp diseases in Malaysia, mostly generic imports from China and Thailand. Commonly used antibiotics include sulphonamides, tetracyclines, nitrofurans, chloramphenicol, oxolinic acid and virginiamycin. However, the amounts used, how the farmers obtained and administered the antimicrobials and whether they were prescribed by licensed authorities, were not clearly indicated in the report.

Present information on the use of antimicrobials in aquaculture in Malaysia has not been updated. The use of antimicrobials on farms has been reported by word of mouth with no documentation or evidence provided. To attain valid information, the DOF is, at present, carrying out AMU surveys among farmers, aquaculture business operators and aquatic animal health professionals to obtain the latest information.

National regulations pertaining to supply, sale and use of antimicrobials

The supply, sale and use of antimicrobials in Malaysia are regulated by laws or regulations under the Poison Act No. 366, 1952 and Poison Regulation, 1952 under the Ministry of Health. There are also other acts and regulations that indirectly control the use of antimicrobials in Malaysia (Table 1).

Agencies responsible for regulation and monitoring of AMU and AMR in aquaculture

The DOF is responsible for the regulation and monitoring of AMU and AMR in aquaculture. The DOF is mandated with the Fisheries Act No. 317, 1985 which addresses the health of aquaculture species, including the prevention and control of aquatic diseases. It also carries out various functions related to the control of AMR such as:

- Registration of aquaculture farms;
- Coordination of national fish disease surveillance programmes;
- Public health monitoring programmes;
- Development of fisheries biosecurity protocols;
- Adoption of MS 1998:2007 – Good Aquaculture Practice (GAqP);
- Inspection of registered aquaculture farms by the State Biosecurity Unit, DOF;
- Assisting in enforcement of the Feed Act, 2009;
- Management of imports, exports and internal movements of live fish; and
- Fisheries biosecurity certification for aquaculture farms – Malaysia Good Agricultural Practices (MyGAP).

Besides the Fisheries Act, 1985, the introduction of the Inland Fisheries Aquaculture Rules, 2017 has further empowered the DOF in monitoring and controlling the use of chemicals including antibiotics in aquaculture. Section 29 of the Rules states that any licensee shall not use any aquaculture chemicals except with the approval of the Director-General of Fisheries and any licensee who contravenes this commits an offence. In East Malaysia, the Inland Fisheries and Aquaculture Enactment, 2003 of Sabah and the State Fisheries Ordinance, 2003 of Sarawak are the two regulations associated with regulating and monitoring antibiotic use in aquaculture. Besides these legislations, there are also the European Commission Guidelines for the prudent use of antimicrobials in veterinary medicine including the aquaculture sector especially for products to be exported to the EU.

The monitoring and control of the use of antibiotics in aquaculture is further supported by DOF active surveillance programmes such as the Aquaculture Residue Monitoring Program and Sanitary and Phyto-Sanitary measures. Encouragement of the prudent use of antibiotics in aquaculture is accomplished through the MyGAP Certification Program.

Table 1. Regulations pertaining to the supply, sale and use of antibiotics in Malaysia

Law/ regulation	**Act 728 Malaysian Quarantine and Inspection Services Act, 2011**	**Act 366 Poison Act, 1952**	**Act 968 Feed Act, 2009**	**Act 281 Food Act, 1983 & Regulation (revision 5 October 2016)**
Scope	Enforce all written laws that are related to ensure that the plants, animals, carcasses, fish, a gricultural produce, soils, micro-organisms and food that are imported into and exported out of Malaysia comply with the health aspects of human, animal, plant, fish and food safety.	Regulate the import, possession, manufacture, compounding, storage, transport, sale and use of poisons. 'Poison' means any substance specified by name in the first column of the Poisons List and includes any preparation, solution, compound, mixture or natural substance containing such substances, other than exempted preparations or articles or preparations included for the time being in the Second Schedule.	Establish the Feed Board to regulate feed quality by controlling the import, manufacture, sale and use of feed and feed additives to ensure that the feed satisfies the nutritional requirements of animals, is not harmful to animals and is not contaminated so that animals and animal products are safe for human consumption and other usage, and for other matters incidental thereto.	Protect the public against health hazards and fraud in the preparation, sale and use of food, and for matters incidental thereto or connected therewith.
Clause/ article/part/ schedule	Part V: Permit, license and certificate	Poison Act, 1952 List – First Schedule Section 18: Restriction on the Sale of Part 1 Poisons Generally	Part V: Control of Antibiotics, Hormones and Chemicals in Feed (License to Import Feed or Feed Additives) Regulation, 2012	15th A Schedule, Regulation 40, Drugs and Residues, Tables 1 and II

List of approved and banned antimicrobials in aquaculture

According to the National Pharmaceutical Control Bureau (NPCB) of the Ministry of Health, Malaysia, there are currently 97 different antimicrobials registered for use in livestock (Table 2). Most of these registered drugs are used in poultry and pig farms, and to a lesser extent in cattle and goat farms. There are no antibiotics registered by the NPCB for specific use in aquaculture. Although there is no list of approved drugs for aquaculture, there is a list of banned drugs in Malaysia. Nitrofurans and chloramphenicol are two drugs banned for use in animals producing food including fish, through aquaculture activities (Food Act, 1983).

At present, the DOF uses the 'Guidelines for the Use of Chemicals in Aquaculture and Measures to Eliminate the Use of Harmful Chemicals (2013)' issued by the ASEAN Secretariat as a reference. According to the Guidelines, the main antimicrobials which can be used in aquaculture in Malaysia are tetracycline, erythromycin, ebazine, sulphonamides, oxytetracycline, sulphamerazine, nitrofirinol and amoxicillin. The use of nitrofurans chloramphenicol, nitroidazole and malachite green is prohibited.

Table 2. Registered antimicrobials for use in agriculture specifically for livestock production

Group of drugs	Active ingredients	No. of products
β-lactam	Ampicillin, amoxicillin	8
Sulphonamides	Sulphamethazine, sulphadiazine, sulphachloropyrazine, sulphadimethoxine, sulphaquinoxaline	8
Tetracyclines	Chlortetracycline, oxytetracycline, doxycycline	13
Cephalosporins	Ceftiofur, cefadroxil, cefadroxil	3
Macrolides	Tylosin, erythromycin, spiramycin, tylvalosin	10
Aminoglycosides	Neomycin, gentamicin	2
Fluoroquinolones	Flumequine, enrofloxacin	8

Source: Food Act , 1983.

National action plan/strategy on AMU and AMR

The Malaysian National Action Plan on AMR (MyAp-AMR) was officially launched by both the Minister of Health and the Minister of Agriculture and Agro-based Industries on 27 February 2018 in Putrajaya. MyAp-AMR sets the framework for the national response to AMR, especially bacterial resistance to antibiotics. It is aligned with WHO's Global Action Plan on AMR and the standards and guidelines established by intergovernmental bodies such as FAO and the OIE. MyAp-AMR aims to reduce the emergence and prevent the spread of AMR bacteria through four core strategies:

- Awareness and education;
- Surveillance and risk assessment;
- Prevention and control of infection; and
- Appropriate use of antimicrobials.

The DOF has initiated plans and activities concerning AMR since the establishment of the NARC in 2016. The DOF's AMR aquaculture working group was established in April 2017 to carry out implementation. At the same time, the DOF has also participated in the FAO Project 'Strengthening Capacities, Policies and National Action Plans on Prudent and Responsible Use of Antimicrobials in Fisheries' which held workshops in India (10 to 13 April 2017), Putrajaya (7 to 9 August 2017) and Singapore (12 to 14 December 2017). These FAO workshops complemented the activities planned in the MyAp-AMR. The governance mechanisms for AMR in aquaculture in the DOF are shown in Table 3.

Table 3. Governance mechanisms for AMR in aquaculture in Malaysia

Activities	2017	2018
Dialogue session: AMR – Playing our part in combating the crisis (MOH, National Pharmaceutical Regulatory Agency, Department of Veterinary Services (DVS), DOF, Federation of Livestock Farmers Association Malaysia) (led by the MOH)	X	
Establishment of the AMR (aquaculture) Working Group (DOF)	X	
Technical Working Group (TWG) meetings	X	X
AMR (aquaculture) Working Group Meeting (DOF)	X	X
Presenting the NAP AMR (aquaculture) to high-level management of the DOF; subsequently endorsed (DOF)	X	
Coordination meeting of the 4 TWGs on AMR and finalization of the NAP AMR (MOH)	X	X
Development and formalization of the NAP AMR (which incorporates AMR in aquaculture)	X	X
Development of the NAP AMR (aquaculture)		X

Source: Department of Fisheries Malaysia.

As the component for aquaculture is only included briefly in the MyAp-AMR, the NAP AMR (aquaculture) is being prepared to include specific details of plans and activities to be carried out under this scope. The first draft of the NAP AMR (aquaculture) is expected to be ready for presentation to top management for endorsement by October 2018. It also adopts four main strategies in managing and controlling AMR similar to the MyAp-AMR. The activities implemented and planned under these strategies are described hereunder:

Awareness and education: One of the fundamental ways to address AMR in aquaculture is to ensure that fish farms adhere to the best practices for hygiene, biosecurity, fish care and handling. To achieve this, the DOF has to first improve the awareness and understanding of AMR through effective communication, education and training. The first attempt at this will be organizing a series of awareness talks for the farmers, the extension staff of the DOF and the general public. The education and awareness programmes carried out by the DOF in 2017 and 2018 are presented in Tables 4 and 5. For 2019, the DOF plans to implement more awareness programmes for farmers. The DOF has printed simple posters on AMR which have been distributed to local farmers, fish feed manufacturers and aquaculture business operators (Figure 1). The DOF is also preparing to publish reports and articles relevant to AMR in fisheries and disseminate materials pertaining to Best Practices in Aquaculture.

Figure 1. AMR poster distributed to farmers

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Surveillance and risk assessment

Monitoring of AMR: Table 6 presents the list of activities carried out for AMR surveillance from 2017 until July 2018. Under the MyAp-AMR, the DOF focuses on V. parahaemolyticus and E. coli as the target micro-organisms for AMR surveillance. Both isolates represent animal and public health importance. V. parahaemolyticus and E. coli isolates obtained from the DOF active surveillance programme, R&D and diagnostic activities were used (Table 7). The isolates were tested against 14 antibiotics of human and aquaculture interests. Bacterial isolation and antimicrobial susceptibility testing were carried out according to CLSI standard methods together with a control culture (E. coli ATCC 25922) in place. All the information regarding the sampling plan, sample preparation, bacterial isolation and antibiotics susceptibility testing methods are specified in the National Integrated AMR Surveillance Manual which is in the second draft of preparation. A workshop was held on the 13 August 2018 in University Putra Malaysia, Serdang Selangor to finalize the manual.

Table 4. Education and awareness (competent authority level)

Activity/month	2017	2018
MyOHUN National AMR Workshop, Putrajaya (6 to 9 March 2017)	X	
FAO Workshop 1, Mangalore, India (10 to 13 April 2017)	X	
MyOHUN National AMR Workshop, Faculty of Veterinary, University Putra Malaysia (UPM) (31 July to 2 August 2017)	X	
FAO Workshop 2, Putrajaya, Malaysia (7 to 9 August 2017)	X	
WHONet Training (28 to 29 August 2017)	X	X
AST Workshop, Kuala Lumpur (25 to 29 September 2017) (5 to 9 January 2018)	X	X
FAO Workshop 3, Singapore (12 to 14 December 2017)	X	
Asian Regional Workshop on AMR, Penang (26 to 28 March 2018)		X
AST quality control training		X
MyOHUN One Health Integrated AMR Surveillance Manual Finalization Workshop (13 August 2018)		X
Survey on Knowledge, Attitude and Practices (KAP) concerning antibiotics – project meeting (14 August 2018)		X
NARC meeting (17 August 2018)		X

Bacterial isolation was executed at six DOF laboratories namely: (i) Fisheries Biosecurity Laboratory Kuala Lumpur (FBLK); (ii) FBL, Bintawa Sarawak; (iii) FBL, Kuantan, Pahang; (iv) FBL, Selangor; (v) Fisheries Research Institute, Batu Maung, Penang; and (vi) National Fish Health Division, Batu Maung, Penang. All bacterial isolates were sent to FBLKL for confirmation and antibiotic susceptibility testing. A total of 113 E. coli and 75 *V. parahaemolyticus* isolates, obtained from June 2017 to June 2018 were tested for antibiotic susceptibility testing (Figure 2).

The AMR results acquired so far indicate that most of the E. coli isolates are resistant towards erythromycin (82.9 percent), ampicillin (36.4 percent), cefepime (23 percent), tetracycline (15.9 percent), chloramphenicol (14.2 percent), cefotaxime (12.4 percent), streptomycin (12.3 percent) and doxycycline (10.6 percent). There was also a small percentage of resistance against colistin (6.2 percent) and nitrofurantoin (1.8 percent). Most of the *V. parahaemolyticus* isolates were resistant towards ampicillin (86.1 percent). Resistance towards colistin (52 percent) was the second highest in V. parahaemolyticus isolates followed by cefotaxime (5.3 percent), erythromycin (4 percent), doxycline (2.7 percent) and tetracycline (2.7 percent). Susceptibility testing of E. coli and *V. parahaemolyticus* will be continued until 2020.

Table 5. Education and awareness (agriculture sector)

Activity/month	2017	2018
Articles in the Fisheries Bulletin (DOF quarterly bulletin) and other journals	X	X
Presentation on AMR during APA 2017 (Farmers Day) (25 July 2017)	X	
Presentation on AMR during the 'Fisheries Biosecurity Strengthening Course' (1 to 2 August 2017)	X	
AMR Awareness and Stakeholders Consultation (4 August 2017) – presentation and distribution of a fact sheet on AMR	X	
Executive presentation: 'AMR in Fisheries'	X	
Aquaculture Industry Consultation Forum, Penang (17 July 2018)		X
Aquaculture Industry Consultation Forum, Sepang (10 July 2018)		X
Aquaculture Industry Consultation Forum, Terengganu (29 July 2018)		X
Aquaculture Industry Consultation Forum, Putrajaya (7 August 2018)		X

Table 6. Activities carried out under the AMR surveillance programme

Activity	2017	2018
Development of the National Integrated AMR Surveillance Manual	X	X (2nd draft)
Preparation of 6 laboratories to conduct AMR surveillance for V. parahaemolyticus (from shrimp) and *E. coli*	X	X
Bacterial isolation and identification	X	X
Bacterial confirmation and antibiotic susceptibility testing	X	X
WHONET data entry and reporting to NARC	X	X

Table 7. Sources of bacteria isolates for AMR surveillance

Bacterial isolates	Sources of samples (June 2017 to June 2018)	Type of samples	Sampling locations	Number of isolates
E. coli (n = 113)	Sanitary and Phyto-Sanitary Program (Aquaculture)	Catfish tilapia	Kedah, Melaka Perlis, Kelantan, Negeri Sembilan, Penang	36
	National Shellfish Sanitation Program (NSSP)	Green mussels, clams, cockles and etak (freshwater bivalves)	Terengganu, Kelantan, Perak, Johor, Selan-gor, Penang, Kedah	77
***V. parahaemolyticus* (n = 75)**	Sanitary and Phyto-Sanitary Program	Tiger prawn	Sarawak, Perlis, Kedah, Negeri Sembilan, Selangor	26
	NSSP	Green mussels, clams	Sarawak, Melaka, Selangor	11
	R&D	Tiger prawn White shrimp	Perak Confidential[1]	8 14
	Diagnostic cases	Tiger prawn White shrimp	Melaka, Kedah, Penang, Sabah, Perak, Sarawak	14
	Antibiotic Residue Monitoring Program	Tiger prawn	Sarawak	2

[1]Not for disclosure.
Source: Department of Fisheries Malaysia.

Figure 2. AMR surveillance work at the Fisheries Biosecurity Laboratory in Kuala Lumpur

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Prevention and control of infection: Disease prevention strategies are crucial for a sustainable aquaculture industry. As prevention is better than control, it is better to focus on preventing the occurrence of disease rather than treating it. There are many ways to prevent infectious diseases and one of the best is through GAPs. In Malaysia, GAP schemes have been replaced with MyGAP. The new certification was introduced by the MOA on 28 August 2013. It is an internationally recognized certification system which aims to ensure safety and quality of products in the food chain. MyGAP emphasizes good management, farm and premise layout, site selection, adherence to strict hygiene practices, sanitation standards, quarantine protocols and biosecured facilities. Although the certification service is free, applications from farmers are quite slow as the certification is not mandatory.

Other approaches to disease prevention include: (i) improvement of husbandry/management practices; (ii) restriction in fish movement; (iii) use of SPF stock; (iv) implementation of sanitary measures, e.g. water disinfection; (v) use of vaccine, probiotics, prebiotics or herbal preparations; and (vi) destruction of clinically sick fish. A combination of different strategies is recommended for effective prevention of fish diseases.

Appropriate use of antimicrobials

To investigate the current status of AMU in Malaysia, the DOF initiated a preliminary survey in August 2017 during the AMR Awareness and Stakeholders Consultation in Kuala Lumpur which was co-organized with the Malaysian Aquaculture Development Association (MADA). The consultations involved fish farmers, aquaculture business operators, feed manufacturers and aquatic health professionals. The programme started with a session on awareness of AMR before 106 questionnaires were distributed to the respondents. The questionnaire was adopted from FAO and NACA with some modifications. Facilitators from the DOF guided the respondents in answering the questions.

AMU surveys continued in 2018 during the Aquaculture Industry Consultation Forum in Selangor (9 July 2018), Penang (17 July 2018) and Terengganu (29 July 2018). Currently the DOF has analysed 103 survey forms from farmers (n = 77, 74.7 percent), fish feed and drug suppliers (n = 17, 16.5 percent), aquatic animal health professionals (n = 6, 5.8 percent) and fish exporters (n = 4, 3.8 percent). Only 13 out of 77 (16.9 percent) farmers used antibiotics. Regularly used antibiotics were oxytetracycline, erythromycin, amoxicillin, ampicillin, entrofloxacin, trimethorpine-sulphadiazine and florfenicol. Most of the farmers (about 70 percent) used other chemicals (antihelminths and antiparasitics) rather than antibiotics in their operations. Farmers only used antibiotics for treatment purposes with more than 50 percent of the users being aware of guidelines on their usage and relevant lists of antibiotics. However, no prescriptions from licensed professionals for the antibiotics were used.

The information on how to use the antibiotics was obtained from the supplier of the antibiotics. Fish feed suppliers and fish exporters disclaimed use of antibiotics in their operations. The aquatic animal health professionals who participated in this survey admitted that they had never prescribed any antibiotics to farmers for treatment purposes. Further interviews with farmers who admitted using antibiotics in their operations were planned to gain more information on the amount, frequencies and sources of antibiotics used.

The AMU survey will be continued until 2019. Face-to-face interviews will be carried out and more stakeholders (hatcheries, nurseries, grow-out ponds, ornamental fish farms, fish feed manufacturers) will be approached. To get a clearer picture of AMU in Malaysia, there is also a plan to examine all of the DOF's farm audit reports to see whether there is noncompliance or observation on the use of antibiotics in certified farms in Malaysia.

The MOA is very serious about combating inappropriate use of antimicrobials in the agriculture sector in Malaysia. A decision was made during the Animal Feed Board Meeting on 25 June 2018. The board unanimously agreed to stop the use of colistin (polymixin E) in animal feed and animal feed additives for treatment purposes in Malaysia effective from 1 January 2019.

Issues and challenges in the implementations of regulations, plans and strategies for AMU and AMR

- Limited information regarding AMR and AMU status in Malaysia;
- Limited resources for carrying out comprehensive AMR and AMU surveys;
- Inadequate knowledge and skills among the staff involved in carrying out AMU and AMR;
- Poor understanding and awareness on AMR and AMU among stakeholders (farmers, fish feed millers and suppliers, farmers' associations, fisheries officers);
- Enhancing communication among relevant departments and ministries (e.g. the MOH, DVS and DOF) so that information on the import, sale and use of antibiotics in Malaysia (for agriculture) is easily shared; and

- The Food Act, 1983 (revised in 2016) and Feed Act (2009) do not include specifications on antibiotics to be used in aquaculture, including lists of approved antibiotics and MRLs permitted.

Conclusion

Malaysia still has a long way to go in evaluating AMR and AMU in aquaculture. The activities carried out so far are still at the preliminary stage and are too premature to be able to assess the AMR risk in aquaculture in Malaysia. The AMR and AMU surveys need to be continued to obtain adequate data to ascertain the quantity of the antimicrobials used, their sources and linkages between antimicrobial use and resistance frequencies observed. The education, awareness and appropriate use of antimicrobials should be continually advocated to ensure that farmers really understand the potential danger of AMR and thus support measures to control AMR in aquaculture. It is very much hoped that all stakeholders will work together in managing AMR in Malaysia.

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Country case study 5 Assessment report on AMU and AMR risk in aquaculture in the Philippines

Sonia S. Somga,[1] Simeona E. Regidor[1] and Joselito R. Somga[2]
[1]National Fisheries Laboratory Division, [2]Fisheries Quarantine Section
Bureau of Fisheries and Aquatic Resources
860 Arcadia Bldg., Quezon Avenue, Quezon City, the Philippines

Introduction

The Philippines is ranked nine among the top fish-producing countries globally with total production of 4.5 million tonnes, about 2.3 percent of the total world production of 199.7 million tonnes. Aquaculture production of fish, crustaceans and molluscs at 0.782 million tonnes is the eleventh highest in the world, sharing 1.02 percent of the world aquaculture production of 76.6 million tonnes and is valued at over USD 1.87 billion (FAO, 2017). About 50 percent of the country's fisheries production is contributed by the aquaculture subsector at about 2.20 million tonnes (50.5 percent) valued at PHP 91.14 billion. Municipal fisheries contributed 1.14 million tonnes (26.1 percent) valued at PHP 78.93 billion, while commercial fisheries production of 1.02 million tonnes (23.3 percent) was valued at PHP 58.87 billion. (BFAR, 2016).

Aquaculture production comes from brackishwater and freshwater fishponds, marine and freshwater pens and cages, and mariculture of oysters, mussels and seaweed. The major aquacultured species are seaweed, milkfish, tilapia and shrimps (Table 1). Shrimps/prawns, the third export commodity, contributed USD 51 million to the country's total fisheries exports (BFAR, 2016).

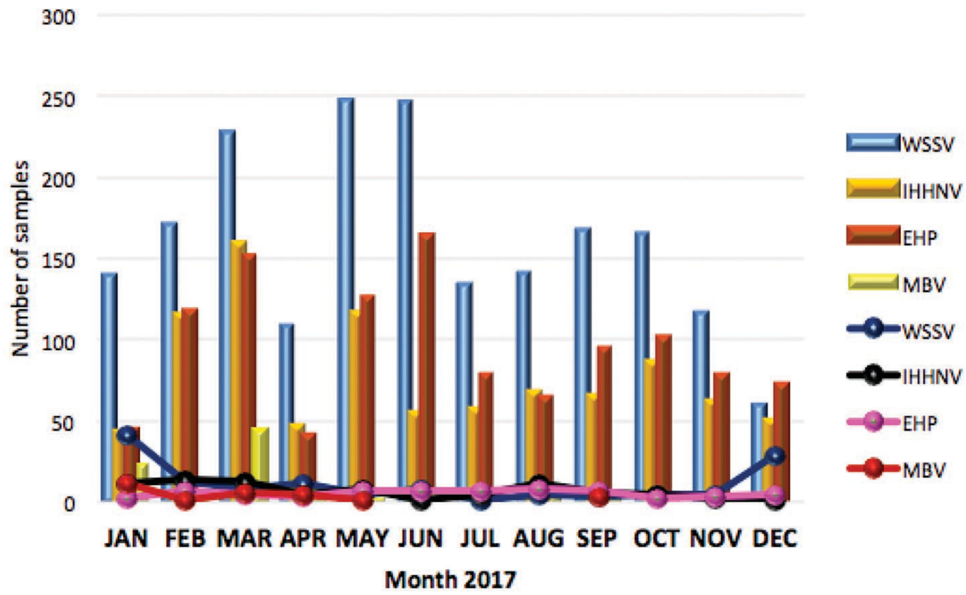
Table 1. Major species produced in aquaculture fisheries, 2016

Species	Quantity (tonnes)	Percent
Seaweed	1 404 519	63.82
Milkfish	398 088	18.09
Tilapia	259 045	11.77
Shrimps/prawns	51 449	2.34
Others	87 813	3.99
Total	**2 200 913**	**100**

Source: BFAR, 2016.

The two major cultured shrimp species are Penaeus monodon and P. vannamei. However, in recent years, P. vannamei has usually been cultured in intensive grow-out systems. White spot disease in shrimp has caused massive mortalities and continues to cause economic losses among shrimp farmers. Since its first reported case in 2000, it is still the most significant disease of shrimp in the country. Other diseases detected in shrimp include: (a) infectious hypodermal and hematopoietic necrosis virus (IHHNV) that causes stunted growth, (b) hepatopacreatic microsporidiasis caused by Enterocytozoon hepatopenaei (EHP) that affects growth resulting in broken sizes and (c) monodon baculovirus (MBV) which is detected during the screening of shrimp postlarvae from hatcheries (Figure 1).

Figure 1. Results of analysis of samples for national surveillance on shrimp diseases conducted by the BFAR Central and Regional Fish Health Laboratories in 2017



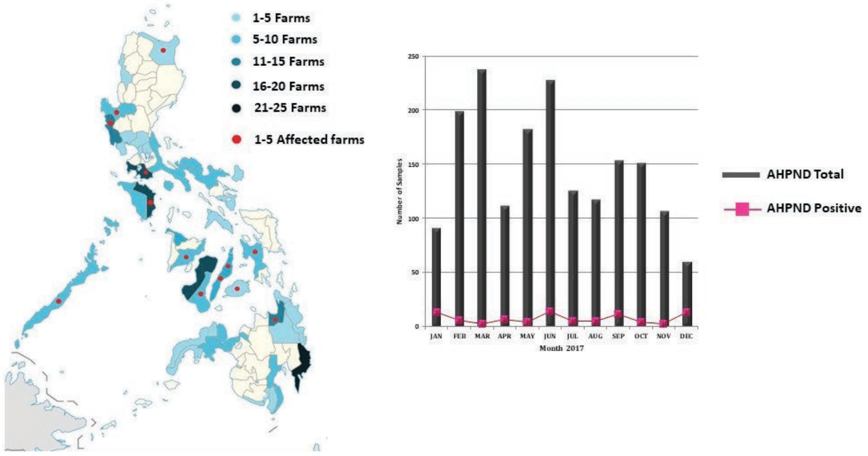
Source: BFAR – National Fisheries Laboratory Division.

Acute hepatopancreatic necrosis disease (AHPND), which was first reported in 2014 by the Bureau of Fisheries and Aquatic Resources (BFAR), also has significant outbreaks, particularly during the early stage of grow-out culture (Figure 2) and has also been observed at late stages of the culture period. There are also cases of mixed infection of AHPND with other viruses in P. vannamei during grow-out culture.

A national surveillance programme is being conducted by BFAR for World Organisation for Animal Health (OIE)-listed diseases in shrimp. Among the list, the above-mentioned diseases have been detected either in hatcheries or grow-out farms. Farmers also submit fry/postlarvae samples to the laboratory for analysis for screening of significant diseases before purchase from hatcheries.

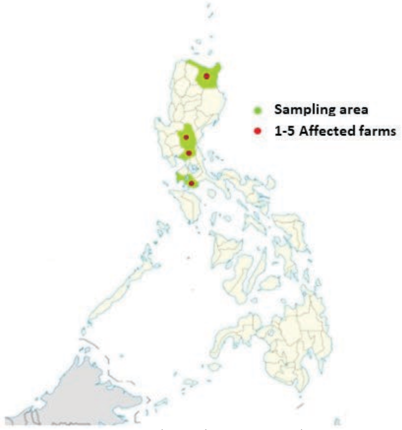
In tilapia, disease is usually associated with bacterial infection caused by Streptococcus agalactiae and Aeromonas hydrophila causing significant mortalities, particularly in high stocking density and poor environmental conditions (Figure 3). In some cases, mixed infections of bacteria and parasites are also encountered.

Figure 2. Results of analysis of samples for national surveillance on AHPND conducted by the BFAR Central and Regional Fish Health Laboratories (2017)



Source: BFAR – National Fisheries Laboratory Division.

Figure 3. Bacteria isolated from diseased tilapia in different Philippine provinces



Province	Important Bacteria Identified
Bulacan	*Streptococcus agalactiae*
	Staphylococcus aureus
	Aeromonas sobria
	Vibrio alginolyticus
Batangas	*Aeromonas sobria*
	Aeromonas hydrophila/caviae
	Staphylococcus xylosus
	Streptococcus agalactiae
Nueva Ecija	*Streptococcus agalactiae*
	Aeromonas hydrophila/caviae

Source: BFAR – National Fisheries Laboratory Division.

Regulations on AMU and AMR in aquaculture

According to the Republic Act 10611 otherwise known as the Food Safety Act, 2013, BFAR is the Food Safety Regulatory Agency responsible for fish and fishery products at the primary production level, including the postharvest stage of the production chain. This includes the use of antimicrobials in aquaculture. The BFAR central office and its 15 regional offices implement the food safety control programme in the fisheries sector. At the central office, the two divisions, namely, the Fisheries Inspection and Quarantine Division and the National Fisheries Laboratory Division take the lead and coordinate with their regional counterparts (Figures 4 and 5).

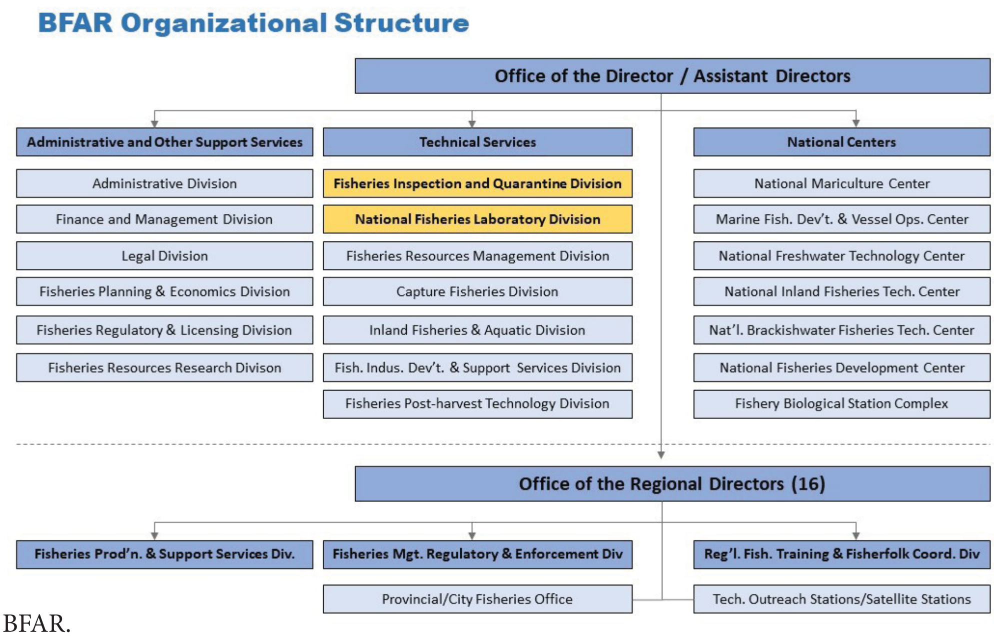
AMU: The regulation of antimicrobials for both humans and animals is under the jurisdiction of the Food and Drug Administration of the Department of Health (FDA-DOH). The Republic Act 9711 otherwise known as the Food and Drug Administration Act, 2009, strengthened the authority of the FDA-DOH to regulate antimicrobials and other products. This includes issuance of licences to operate establishments that manufacture, import/export and distribute antimicrobials, and registration of products prior to marketing and usage.

Through a Joint Administrative Order of the Department of Health (DOH) and Department of Agriculture (DA), the Bureau of Animal Industry (BAI-DA) was delegated to regulate antimicrobial use in animals including aquatic animals. This included registration of veterinary drugs and products such as: (a) pre-mixes, water soluble powder and other preparations added to feed and water, feed supplements, feed additives and other drinking/dipping solutions intended for mass medication for terrestrial and aquatic animals; (b) vaccines, diagnostic kits and reagents, veterinary medical devices and other biological products.

The FDA-DOH is in charge of registration of veterinary drugs and products such as: (a) finished pharmaceutical dosage forms – oral dosage, capsules, tablets, paste, powder for suspension, granules for suspension, solutions, syrup and emulsion; (b) injectables such as solutions, suspensions in powder, granules; and (c) external preparations such as topical, suspension, cream, ointment, lotion, aerosol, paste, spray, gel and powder treatments. With the enactment of the Food Safety Act, 2013, the DA has provided the authority to regulate the use of antimicrobials and other products in the agriculture sector. At present, the DA (BAI and BFAR) and FDA-DOH are developing a mechanism on control of antimicrobials in the livestock sector delineating terrestrial and aquatic disciplines.

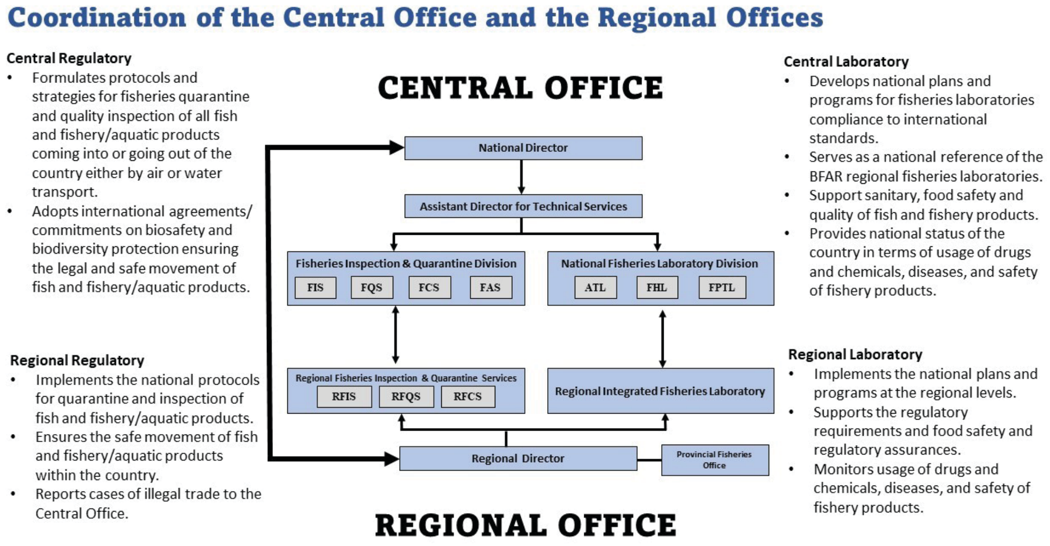
BFAR implements a national residue control programme, based on DA-Administrative Order No. 14 series of 2006. The programme aims to detect illegal treatments, particularly banned antibiotics, and control compliance with the MRLs of veterinary drugs and other contaminants. The programme includes monitoring of targeted substances at farms, aquatic feedmills, auction markets and processing plants. Monitoring at aquatic feedmills is relevant to the BAI-DA because it is the agency mandated to regulate feedmills. Administrative orders on the regulation of AMU and banning of selected antimicrobials are listed in Tables 2 and 3.

Figure 4. BFAR organizational structure



Source: BFAR.

Figure 5. Coordination among central and regional offices of BFAR in the implementation of programmes related to food safety control



Source: BFAR.

AMR: BFAR is responsible for the implementation of programmes on AMR in aquaculture. RA 8550, otherwise known as the Fisheries Code of 1998 and amended by RA 10654 on the control of illegal, unreported and unregulated fishing, is mandated with the conservation and management of fisheries and aquatic resources. BFAR is also the Food Safety Regulatory Agency for the fisheries sector as provided in the Food Safety Act, 2013. The National Action Plan (NAP) to combat AMR under the One Health initiative is an interagency collaborative activity developed through the Administrative Order No. 42 series of 2014, which is co-chaired by the DOH and DA with members from the Department of Science and Technology, Department of Interior and Local Government, and Department of Trade and Industry. The programme has been initiated in support of WHO's endorsement of the One Health initiative to combat AMR during the 2011 World Health Assembly. The NAP was launched in 2015 during the First Philippine AMR Summit.

At the national level, BFAR's National Fisheries Laboratory Division (NFLD) leads the planning of programmes on AMU and AMR in aquaculture. To facilitate them, a Fisheries Office Order was issued for the designation of a regional focal person for this purpose. Table 4 lists the rules and regulations on the implementation of AMR in aquaculture.

Antimicrobial use in aquaculture

Several surveys have been conducted on the use of antimicrobials in aquaculture. The 1995/1996 survey conducted by Cruz-Lacierda, Dela Pena and Lumanian Mayo (2000) showed that more than 100 products were available in the market for culture, preventive and treatment purposes. Among the antibiotics used in P. monodon hatcheries and grow-out ponds were chloramphenicol and nitrofurans, with malachite green as the fungicide. These antibiotics and fungicides are already banned in the Philippines for use in food-producing animals including aquatic animals. Cruz-Lacierda, dela Peña and Lumanlan-Mayo (2000) listed the adverse impacts of indiscriminate use of these chemicals.

In 2009, the Philippines participated in the FAO project on 'Improving Biosecurity through Prudent and Responsible Use of Veterinary Medicines in Aquatic Food Production'. A survey on the use of veterinary medicine in Philippine aquaculture was conducted by Somga, Somga and Regidor (2012) covering different key players in aquaculture production. The survey revealed that more antibiotics were being used in aquaculture. Most of these antibiotics are allowed for use in livestock and have recommended MRLs set by the Codex Alimentarius and the EU in seafood products for human consumption. The survey proved that farmers recognized both positive and negative impacts of AMU. Although the use of antimicrobials could generally increase survival rates and reduce mortalities during disease events, there were cases where farmers observed that antimicrobials, particularly antibiotics, were no longer effective when continuously applied. Instead, farmers used probiotics applied in feed and water.

Table 2. Administrative Orders relative to regulation on AMU

Administrative Order (AO)/circulars	Purpose
JOINT DOH and DA AO No. 2013-0026	Rules on the regulation of veterinary drugs and products, veterinary biological products and veterinary drugs outlets
FDA Circular 2014-017	Procedure for the submission and issuance of FDA certification for animal feeds and feed products
FDA Circular 2013-004	Postmarket surveillance of registered health products
AO No. 103 s. 2002	Batch certification of antibiotics
AO No. 27 s. 2001	Rules and regulations for licensing local manufacturers of vaccines and biological products
DOH AO No. 111-D s. 1991 (DA AO No. 41 s. 1991)	Guidelines on advertisement and promotion of veterinary drugs and products
DOH AO 111-A/DA AO No. 33 s. 1991	Rules and regulations on registration of veterinary drugs and products
AO No. 25 s. 1991	Registration and licensing of veterinary drugs, product premixes and water solubles and the corresponding manufacturers, importers, suppliers, distributors and retailers of said products with the Animal Feeds Standard Division
DOH AO 105/ DA AO No. 11 s. 1991	Requirement for labelling of veterinary drugs and products
DOH AO 111-B/ DA AO No. 39 s. 1991	Rules and regulations to implement prescribing requirements for veterinary drugs and products
AO No. 100 s. 1990 (DA AO No. 138 s. 1990)	Regulation for the licensing of veterinary drug and product establishments and outlets
DOH AO 40/ DA AO No. 40 s.1990	Rules and regulations on dispensing of veterinary drugs and products
DOH AO 114-B/DA AO 30 s. 1991	Transitional remedial labelling in compliance with RA 6675
AO No. 95 s. 1990	Hiring of veterinarians as consultants for commercial feed manufacturers producing medicated feeds
DA AO No. 14 s. 2006	Implementation of the National Veterinary Drug Residues Control Program and creation of interagency committees
DA AO No. 24 s. 2009	Implementing guidelines on the National Veterinary Drug Residues Control Program in Foods Pursuant to AO 14, Series of 2016

Sources: FDA and BAI Web sites.

Table 3. List of banned antimicrobials in food animals including aquatic resources

Administrative Circular (AC)/ Administrative Order (AO)	Purpose
BFAR-AC No. 256 s. 2015	Declaring malachite green and gentian violet as health hazards and prohibiting their use in food fish production and trade
DA AO No. 14 s. 2003	Ban on the use in food animals of beta-agonist drugs used in humans as bronchodilators and tocolytic agents
DOH and DA Joint AO No. 2 s. 2000	Declaring ban/phase out of the use of nitrofurans in food-producing animals
DOH AO No. 4-A and DA AO No. 1 s. 2000	Banning and withdrawal of olaquindox and carbadox from the market
DOH AO No. 91 and DA AO No. 60 s. 2000	Declaring ban on the use of chloramphenicol in food-producing animals
DOH AO No. 341 s 1978	Ban on the use of chloroform (trichloromethane)
DOH AO 194 s 1973	Ban on the use of diethylstilbestrol (DES)

Sources: FDA and BAI Web sites.

Table 4. Rules and regulations relative to the implementation of AMR in aquaculture

Regulation	Purpose
Republic Act (RA) 8550	Provide for the development and conservation of fisheries and aquatic resources, integration of all laws pertinent thereto, and for other purposes
RA 10654	Deter and eliminate illegal unreported and unregulated fishing, amending Republic Act 8550. This requires compliance to GAPs and provides penalties if noncompliance results in major catastrophic events specified in law
RA 10611	Strengthen the food safety regulatory system in the country to protect consumer health and facilitate market access to local foods and food products and for other purposes
AO No. 2014-42	Create an inter-agency committee for the formulation and implementation of a National Plan to Combat Antimicrobial Resistance in the Philippines
Fisheries Office Order (FOO) No.104 s. 2018	Designation of BFAR Antimicrobial Resistance (BFAR-AMR) coordinators for better engagement and smooth implementation of programmes and activities to address AMR issues

Source: Department of Agriculture – BFAR.

The survey also highlighted that accurate diagnosis is important for appropriate treatment regimes including the availability of approved veterinary medicines/drugs for use in aquaculture. Concerns on food safety in terms of residue build up in aquaculture products and clinical resistance were noted, but the need to put more effort into providing information for and raising awareness among stakeholders on these issues was noted. The antibiotics identified in this survey were included in the list of substances that are being monitored by BFAR as part of its national residues control programme. In this context, BFAR implements farm registration schemes based on GAPs. Farm registration includes documentation regarding the operation of the farm and inspection and sampling for disease surveillance and residue monitoring. Farm registration is renewable every two years if compliance with requirements is followed.

In 2018, a project with FAO FMM/RAS/298 on strengthening capacities, policies and national action plans on prudent and responsible use of antimicrobials in fisheries was implemented. It includes: (i) documentation of AMU (possibly AMR) surveillance and informal surveys, (ii) enhancing capacities on careful use of antimicrobials, good biosecurity, husbandry and best practices, and (iii) promoting advocacy, communication and education activities. The project served as a guide in the implementation of the aquaculture component of the NAP and in setting up an AMR surveillance plan. The project targeted tilapia and shrimp aquaculture, and established baseline data on AMU via surveys. According to the country report of Regidor and Somga (2018) most of the farmers, particularly shrimp farmers, used probiotics. The only antimicrobial cited in aquaculture was oxytetracycline, which is widely used in cultured species. This corresponds with the result of the national residues control programme where oxytetracycline was detected in aquatic feed and some shrimp samples. A list of antimicrobials and other products used by farmers that are available on the market is given in Table 5.

Most of the farmers surveyed were aware of the national regulations on the use of antimicrobials and were familiar with banned and regulated antibiotics. However, there is a need to continue advocacy in promoting GAPs and training the farmers to adopt recommended management practices on the prudent use of antimicrobials. This is a continuing activity at the regional level to help them improve their practices.

Table 5. Commercially available antimicrobials/chemicals/products used in aquaculture

Type of antimicrobials/ chemicals/ products	Commercial name	Application	Dosage and administration	Purpose	Withdrawal period
1. Probiotics	Sanolife Nutrilake	During pond preparation	35 kg/ha to 50 kg/ha	Prevention	N/A
		During culture	3 kg/ha to 5 kg/ha		
	Pro Tab	Feed	Day 0–30: 100 g/kg of feed Day 30–60: 50 g/kg Day 60–harvest: 10 g/kg	Prevention	N/A
	MIC	Water	1 g/500 ml sterile seawater Zoea: 0.5 ppm Mysis, PL, maturation: 1.0 ppm	Prevention	N/A

Type of antimicrobials/ chemicals/ products	Commercial name	Application	Dosage and administration	Purpose	Withdrawal period
	pH Fixer	Water	5 kg/ha to 10 kg/ha	Prevention	N/A
	C.P. Bio Plus	Water	DOC 1–30: 4 kg/ha/ week DOC 31–60: 5 kg/ ha/week DOC 61–120: 6 kg/ ha/week	Prevention	N/A
	Super Biotic	Water	3 kg to 12 kg/ha	Prevention	N/A
	Super PS	Water	Pond preparation: 20 L/ha, mixed with water or lime DOC 1–120: 60 L/ha/week	Prevention	N/A
	Zymetin	Feed	5 g to 10 g/kg of feed	Prevention	N/A
	PondPlus	Water	300 g–1 kg/ha every 7–10 days	Prevention	N/A
	PondDtox	Water	1 kg to 2 kg/ha every 7–10 days	Treatment	N/A
2. Disinfectant	Virkon	Water	1.2 ppm to 2 ppm (12 kg/ha to 20 kg/ha)	Prevention	N/A
3. Antiparasitic	Hadaclean Aqua	Feed	Light infection: 4 g to 6 g/1 kg feed for 3 days OR 1 sachet (100 g) to 25 kg of feed Repeat every 2 weeks if parasites are prevalent Heavy infection: 8 g to 10 g/1 kg feed OR 2 sachets (200 g) to 25 kg of feed Repeat every 2 weeks if parasites are prevalent	Treatment	3 days before harvest
4. Immuno-stimulant	S-Pak	Feed	Before and after stress conditions/ disease: 20 % to 25 % of crumbs for 3 days before and after shipment	Prevention	N/A
5. Supplement	Hi 5 Artemia	Water	2 g (1/4 spoon) of inert feed/L/day 2–3 x daily	Prevention	N/A
	Frippak	Water	50 g/L suspension then poured into filter screen before distributing in the tanks	Prevention	N/A

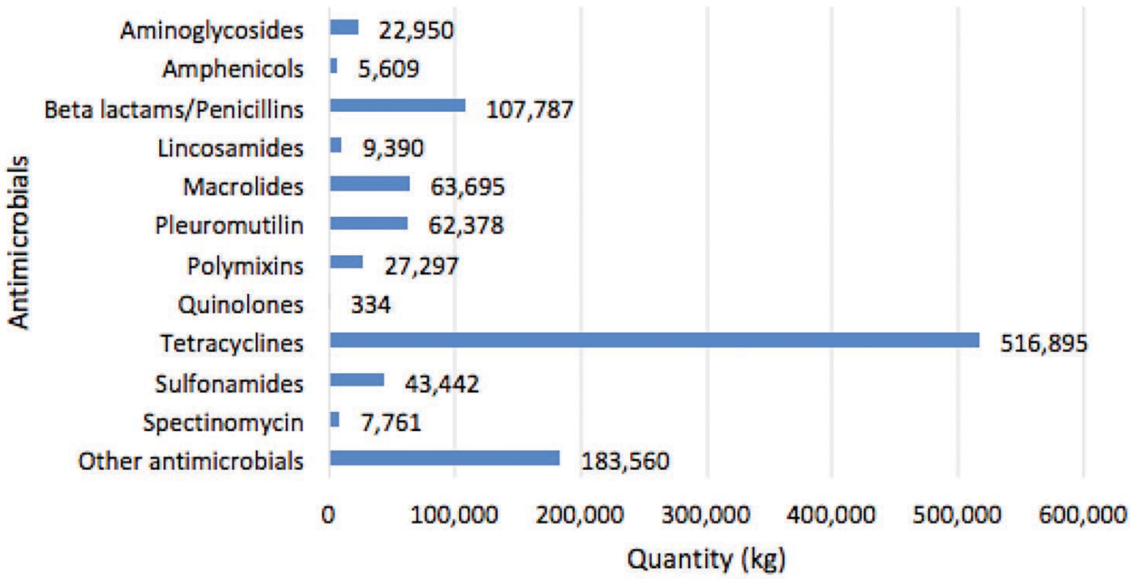
Type of antimicrobials/ chemicals/ products	Commercial name	Application	Dosage and administration	Purpose	Withdrawal period
	Lansy	Feed	11 g to 62 g/100 000 pl/day split into 4 rations	Prevention	N/A
	Breed-S	Feed	N/A	Nutrition	N/A
	D100 D-150 Aqua G	Water	-	Prevention	N/A
5. Supplement	Coforta Aqua	Water	3 kg to 5 kg feed for 3 days straight (2 meals: repeat when applicable every 15 days)	Nutrition	N/A
	Latibon Plus	Feed	1 kg to 3 kg/tonne feed at all feeding times	Prevention	N/A
	Stomi	Feed	10 kg to 20 kg/ha every 7 to 10 days	Prevention	N/A
	Hi Power	Water	Pond preparation: 100 kg to 250 kg/ha During culture: 10 kg to 25 kg/ha	Prevention	N/A
6. Water conditioner	AFM	Water	Controlling ammonia levels: 3 L/10 000 m2/metre depth once every 2 weeks Instant reduction of ammonia: 3 L/1 M ha depth for 3 days	Prevention & treatment	N/A
	Deocare Aqua	Water	1 kg/2–3 tonnes biomass	Prevention	N/A
7. Pesticide	Teaseed	Water	15 ppm to 25 ppm at 0.3 m–3 m water depth for 2 to 3 days after pumping in water High infestation of pest snails: 30 ppm to 50 ppm	Prevention & treatment	N/A

Sources: BAYER Philippines, CP, Philippines, Biosolutions.

Import of antimicrobials

Antimicrobials are either imported or manufactured in the country, with most of the raw materials used for formulation being imported. The data on the importation of antimicrobials for animal use are based on the SPS clearance issued by the BAI-Animal Veterinary Drugs and Biologics Control Division (Figure 6). The data refer to the total volume of imports without specified target species. The FDA-DOH registered importers are not required to obtain SPS clearance and imports are controlled by the Bureau of Customs. Similarly, with locally manufactured antimicrobials, data on the volume of their production and usage are limited.

Figure 6. Import of veterinary drugs for animal use based on SPS clearance, issued by BAI (2015–2016)



Source: Bureau of Animal Industry – Animal Feeds, Veterinary Drugs and Biologics Control Division.

National residues control programme

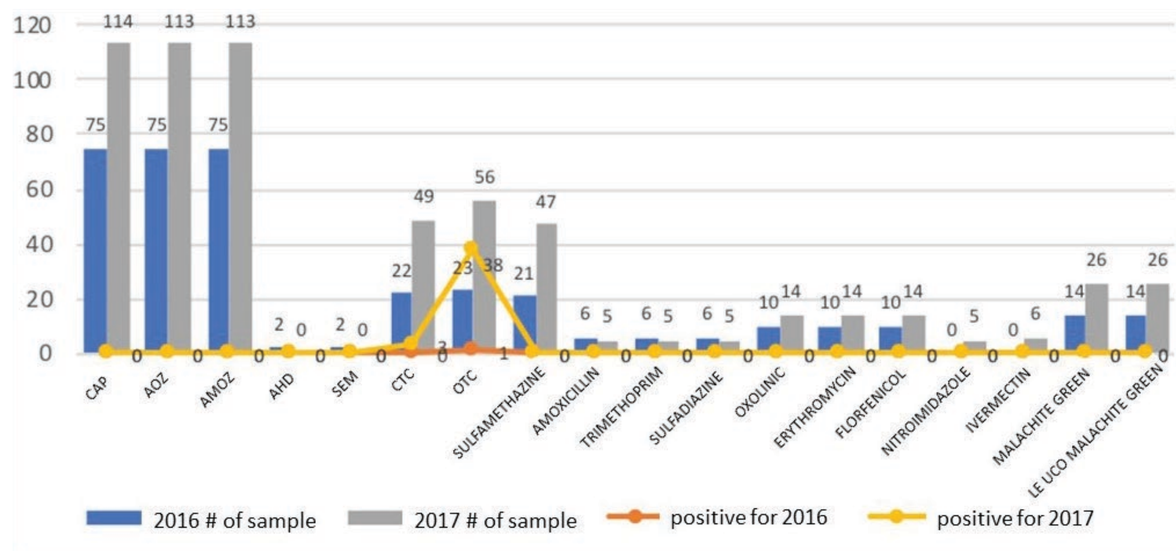
The national residues control programme covers major aquaculture products, i.e. tilapia, milkfish and shrimp. The substances being monitored include banned substances such as chloramphenicol, nitrofurans (AOZ, AMOZ, AHD, SEM), nitroimidazole, diethystilbestrol and malachite green, and substances with MRLs. These substances are identified through the survey conducted on the use of veterinary medicines in Philippine aquaculture (Somga, Somga and Regidor, 2012). Other contaminants, such as pesticides and heavy metals, are also included in the programme.

Samples are taken from farms, auction markets, feedmills and processing plants. Inspections and sampling are conducted by regional fish health officers (FHOs) according to regional targets for each year, which are based on production and results of monitoring in previous years. Sampling at registered aquaculture farms considers the risk of using antibiotics, in case of health or disease problems or other challenging conditions, based on environmental/water quality at the time of visit. Farms where antibiotic or contaminant levels exceed MRLs are notified through the regional FHOs. The farmers are then advised to trace the source of contamination and to implement an appropriate withdrawal period before harvest. These farms are subjected to more frequent sampling for antibiotic residue analysis. Figures 7 to 10 show the results of national surveillance and monitoring on antibiotic residues in shrimp, tilapia and aquatic feeds (2016 to 2017) and milkfish (2017), respectively.

National action plan on AMR

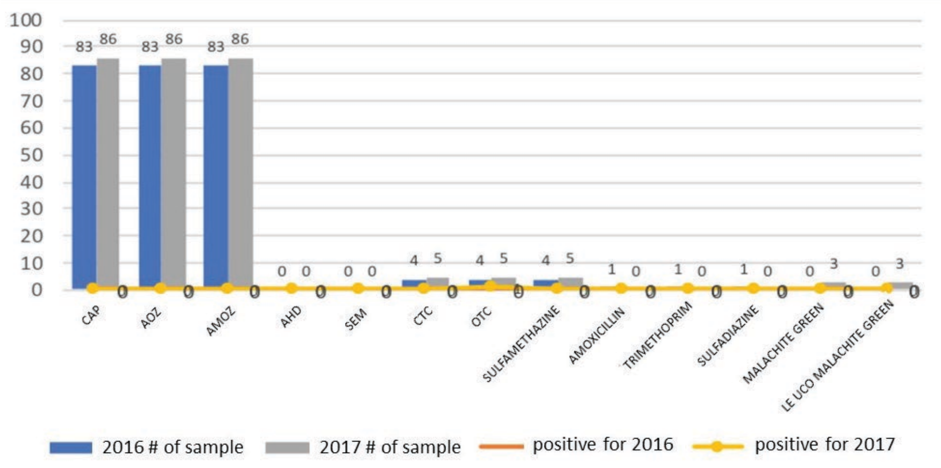
The NAP to combat AMR under the One Health initiative involves several agencies at the DOH and DA, and has seven key strategies: 1) commit to a comprehensive, financed national plan with accountability and civil society engagement; 2) strengthen surveillance and laboratory capacity; 3) ensure uninterrupted access to essential medicines of assured quality; 4) regulate and promote the rational use of medicines in the human and animal health sectors; 5) enhance infection prevention and control across all settings; 6) foster innovation, research and development; and 7) development of a risk communication plan to combat AMR.

Figure 7. Results of national surveillance and monitoring on antibiotic residues in shrimps (2016 to 2017)



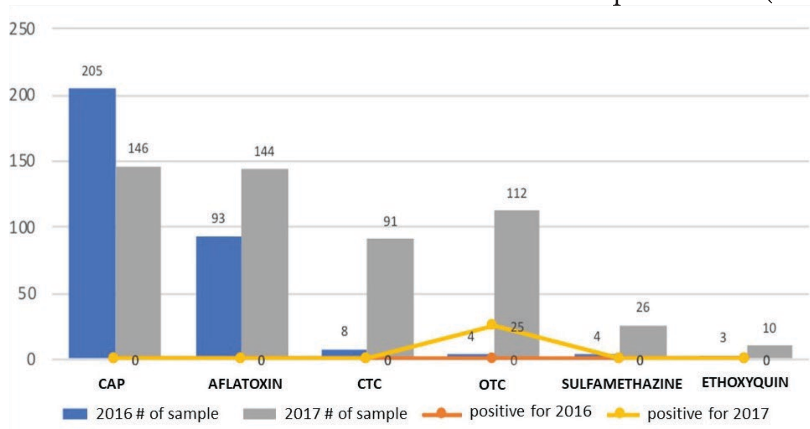
Source: BFAR – National Fisheries Laboratory Division.

Figure 8. Results of national surveillance and monitoring of antibiotic residues in tilapia (2016 to 2017)



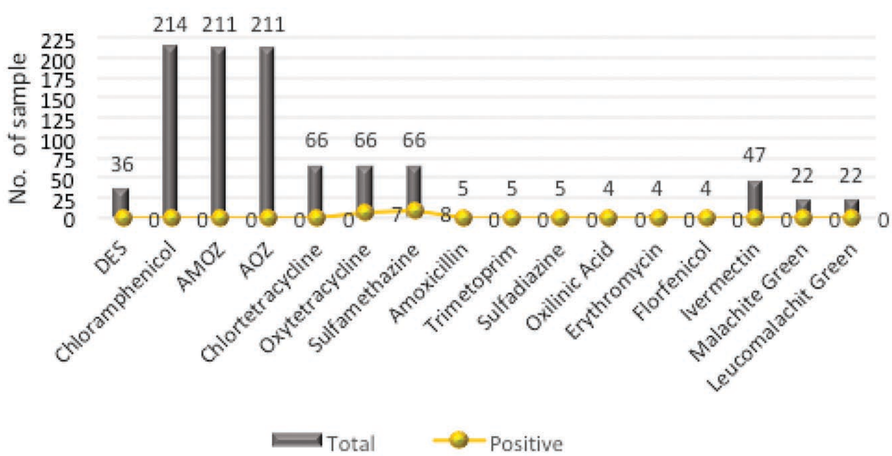
Source: BFAR - National Fisheries Laboratory Division.

Figure 9. Results of national surveillance on antibiotics in aquatic feeds (2016 to 2017)



Source: BFAR – National Fisheries Laboratory Division.

Figure 10. Results of national surveillance on antibiotics in milkfish (2017)



Source: BFAR – National Fisheries Laboratory Division.

Each agency involved has tasks to achieve set targets and objectives. The aquaculture component was provided with assistance from FAO project FMM/RAS/298 and implementation of activities for each strategy followed the FAO action plan that focuses on the four pillars of awareness-raising, good governance, developing evidence-based guidelines and following best practices.

Awareness-raising: Awareness-raising within BFAR and workshops was conducted with the regional FHOs as part of the FAO aquatic AMR project. Training events to strengthen the skills of laboratory analysts on fish health, diagnostic methods for detection of important diseases, sampling and standard procedures were conducted in 2017. This was part of ongoing staff development and harmonization between and among regional laboratories on fish health activities.

Information on AMU and AMR was disseminated to tilapia and shrimp stakeholders via a food safety roadshow at which policies and GAqPs were highlighted. Updates on judicious use of antimicrobials was also part of GAqP training conducted in Luzon, Visayas and Mindanao through the EU-TRTA 3 project. BFAR also participated in the Antibiotic Awareness Week of the Department of Agriculture supported by FAO–Philippines which was attended by key stakeholders (manufacturers, distributors, organizations, the academe, farmers). This activity also discussed aquaculture practices in intensive shrimp farming with emphasis on food safety, animal health and good practices. Continuing awareness-raising on AMU and AMR will be incorporated in seminar training activities that will be conducted for stakeholders. To strengthen awareness on GAqP, an explanatory brochure on GAqP standard requirements is being developed together with the Bureau of Agriculture and Fisheries Standard (BAFS).

Good governance: Republic Act (RA) 8550 supports the implementation of AMR activities, including GAPs. Republic Act 10611 provides BFAR with the authority to enforce food safety standards and regulations at the primary production and postharvest stages of the production chain. Administrative Order No. 42 s. 2014 for the creation of an interagency committee to formulate and implement the NAP in AMR and Fisheries Office Order No. 14 s. 2018 designating BFAR-AMR coordinators for implementation of activities on AMR, were also issued.

To improve registration, marketing authorization and postmarketing surveillance of antimicrobials, there are several target activities, namely:

- Agreement on regulatory control over veterinary drugs used in aquaculture;
- Quality monitoring of veterinary drugs (registered and unregistered); and
- Data collection of registered antimicrobials, including quantitative production and importation information.

Evidence-based guidelines: At present, the national residues control programme is being implemented to monitor usage of antimicrobials in aquaculture with emphasis on banned antibiotics and those antibiotics that are allowed in food-producing animals with MRLs. The surveillance plan for AMR in aquaculture (developed as part of the FAO project) is now integrated in the FAO–Philippines project that supports the DA AMR activities. The DA AMR has three components: poultry, livestock and aquaculture. Component 3 (aquaculture) will undertake AMR surveillance in bacterial pathogens from diseased aquatic animals, specifically tilapia, milkfish and shrimp. This runs parallel to surveillance in the human sector where samples come from diagnosed disease cases. Its objective is to develop evidence-based clinical guidelines for veterinarians on the proper use of antimicrobials in aquatic animals.

A system for surveillance and monitoring of AMR is planned for 2019. Training of laboratory analysts on detection of AMR in aquaculture has already been conducted at the BAI laboratory. Procurement of supplies and materials for laboratory analysis for AMR is underway. AMR surveillance, including sampling, analysis and reporting will commence in January 2019.

Best practices: For the programmes on infection prevention and control and strengthening of animal health system capacity, BFAR conducts advocacy and promotion among stakeholders through seminars and training on implementation of GAqPs in farm operations and setting up biosecurity measures. IEC information, education campaign materials for GAqPs and biosecurity measures are also disseminated as a continuing activity at the national and regional levels. The BAFS leads in the development of the farm certification scheme for GAqPs together with BFAR.

Issues, gaps and constraints in the implementation of regulations and plans/strategies for AMU/AMR

So far, there is no clear delineation of the function of regulatory agencies for veterinary drugs in aquaculture. Food safety regulatory agencies such as FDA, BAI and BFAR are developing a mechanism for a harmonized system in this context.

There are no data on the volume of importation, manufacture and distribution of antimicrobials in aquaculture. These data are important to determine the supply chain of antimicrobials intended for use in aquatic animals.

Laboratory capacity for surveillance on AMR in aquaculture is insufficient. A training programme on antimicrobial sensitivity testing and MIC specific to aquaculture pathogens and common antibiotics used in aquaculture is needed.

Strategies and actions for addressing AMR risks in aquaculture

- Strengthen the linkages and collaboration with relevant regulatory agencies (FDA, BAI, Bureau of Customs) on data collection and sharing of information on the importation, manufacture and distribution of antimicrobials in animals;

- Develop a monitoring system and determine the usage pattern of antimicrobials in aquatic resources with the involvement of key players and stakeholders;
- Continue the information and education campaign for awareness on prudent use of antimicrobials and AMR through seminars and print media and promote the implementation of GAPs and biosecurity measures for disease prevention and control; and
- There is a need to strengthen laboratory and surveillance capacity for AMR in aquaculture. Develop capacities of laboratories on AMR analysis according to CLSI standards and ISO accreditation.

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Country case study 6 Assessment report on AMU and AMR risk in aquaculture in Singapore

Diana Chee[1] and Kelvin Lim[2]
[1]Ornamental Fish Section (OFS), Aquaculture Technology Department, Sembawang Research Station, Sembawang Road, Lorong Chencharu, Singapore 769193
[2]Surveillance and Inspection Department (SID), Agri-Food & Veterinary Authority of Singapore. 10 Perahu Road, Singapore 718837

Introduction

Singapore has a small but thriving and increasingly important food fish-farming industry which accounts for about 10 percent of local food fish consumption. The main bulk of food fish production comes from coastal fish farming in floating net cages along the Straits of Johor and the Southern Islands. Most of these floating net cages are traditional wooden platforms but some of the farms have cages made of materials like high-density polyethylene (HDPE). There are 114 coastal and deep-sea fish farms (105 food finfish and 9 bivalve farms) and 9 land-based food fish farms that produced about 4 808 tonnes of food finfish in 2017 (Table 1). Common marine food fish species cultured include Asian seabass (Lates calcarifer), groupers (Epinephelus spp.), snappers (Lutjanus spp.), milkfish (Chanos chanos) and mullet (Mugil spp.). Other than finfish, a few coastal farms also produce green mussel (Perna viridis) and oysters (Crassostrea gigas) which form the bulk of shellfish production in Singapore.

Land-based food fish farms mainly culture freshwater species like the giant snakehead (Channa micropeltes) and tilapia (Oreochromis spp.). Other species include jade perch (Scortum barcoo) and catfish (Clarias batrochus). The culture system in traditional land-based farms uses mostly earthen or concrete ponds. Recently, some land-based farms using recirculation aquaculture systems (RAS) technology have been set up, mainly producing groupers and shrimp.

Table 1. Farm production of food finfish in Singapore from 2008 to 2017

	Farm production									
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Locally produced food finfish (tonnes)										
	1 970	2 235	3 186	3 476	3 157	4 220	4 205	5 272	4 851	4 808
Excluding crustaceans and molluscs.										

Source: http://www.ava.gov.sg/Publications/Statistics/

Singapore's local food production target is 15 percent for fish. Presently, local farms are producing only 10 percent of the fish supply. The targets that were set are reviewed from time to time as needs evolve and as technology becomes available. New technologies such as sensors, precision farming, automation, robotics, genetic improvements and other engineering solutions are bringing many opportunities for increasing productivity and raising local production. The Singapore Aquaculture Plan (SAP) outlines the Agri-Food and Veterinary Authority of Singapore (AVA) vision to develop and expand Singapore's aquaculture cluster and has the goal of producing 50 percent of Singapore's fish consumption by 2035. To achieve the goal of the SAP, local production of finfish needs to increase by more than tenfold by 2035.

The control of diseases in aquaculture

Major bacterial diseases in aquacultured species include streptococcosis, nocardiosis, vibriosis and tenacibaculosis. Viral infections with VNNV, scale-drop disease virus and iridoviruses have also been detected. All farms have access to extension and laboratory diagnosis services for the timely and accurate detection of the causative agent of mortalities and morbidities in their stock.

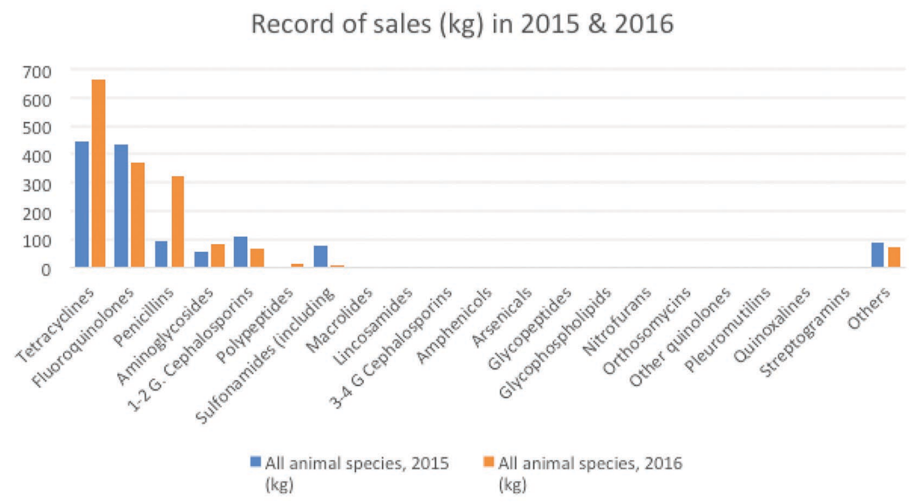
Apart from a few large progressive farms, most fish farms belong to smallholder farmers with diverse education levels. In addition, vaccines for tropical food fish are limited in availability worldwide and are rarely used by smaller farms. The aquaculture industry is the largest user of antimicrobials in animals in Singapore. The AVA is responsible for regulation and monitoring of AMU and AMR in aquaculture. Outreach and education, accreditation schemes, GAPs, facilitation of vaccine provision, development of prudent use of guidelines and strengthening of regulations are some areas the AVA is working on to reduce AMU in the aquaculture industry, especially that which is hazardous to human health.[1]

Use of antimicrobials in aquaculture

From 2015, data on AMU in animals have been collated and reported annually to the OIE. Currently, the sales data are collected through a voluntary survey of wholesalers of veterinary drugs and serve as a proxy for AMU in animals. Figure 1 shows the total reported sales of antimicrobial drugs in 2015 and 2016 from responses of 52 percent (12/23) and 54 percent (14/26) of wholesalers respectively. Figure 2 shows the breakdown by animal sector. Both figures are from the Joint Report on Antimicrobial Utilisation and Resistance in Singapore (in preparation).

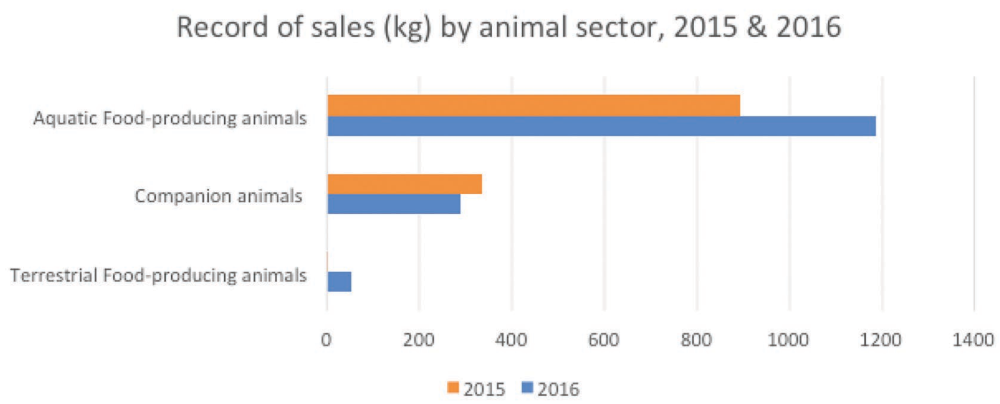
[1] As listed in the WHO List of Critically Important Antimicrobials.

Figure 1. Total reported sales of antimicrobial drugs in 2015 and 2016



Source: Joint Report on Antimicrobial Utilisation and Resistance in Singapore.

Figure 2. Breakdown of sales of antimicrobial drugs by animal sector



Source: Joint Report on Antimicrobial Utilisation and Resistance in Singapore.

The aquaculture industry is the largest user of antimicrobials in animals in Singapore, with 77.5 percent of the antimicrobials sold in 2016 being used in this sector. Sales of antimicrobials in the aquaculture sector increased by 33 percent from 892 kg in 2015 to 1 185 kg in 2016 (Figure 2). However, this has yet to account for the increase in biomass and fish production. Apart from a few large progressive farms, most fish farms are smallholdings and the level of farmers' education is more diverse.

From interviews with farmers, the AVA is aware of enrofloxacin, oxytetracycline and tetracycline being used on farms as medication that is applied to aquaculture feed. Florfenicol, fluoroquinolones, chlortetracycline, tetracycline and sulphamethazine (sulphadimidine) have also been detected in pelleted feed sampled from farms. Medications used in food finfish are top coated onto pellets or trash fish before feeding. This poses a risk to human health from:

- Consumption of fish containing antimicrobial residues in the muscle and fat should withdrawal periods be inadequate; and
- Leaching of antimicrobials from the top-coated fish feed and antimicrobial residues in fish waste into the coastal environment.

List of approved and banned antimicrobials in aquaculture

Singapore has a list of drugs and antimicrobials which are banned for use in livestock. Antimicrobials are not used for growth promotion in Singapore farms. Certain antimicrobials such as nitrofurans, chloramphenicol and avoparcin are prohibited for use in feed and all food-producing livestock and aquaculture farms. This is supported by the legislation. Antibiotics, including permitted drugs, are not allowed in animals ready for slaughter. While there is no specified regulatory withdrawal period for antimicrobials in aquaculture, farms have been advised to follow manufacturer's instructions or to keep to at least 500 degree days' withdrawal period[2] in food fish.

The AVA enforces strict limits on antimicrobial residues in food products, taking regulatory action when drug residues exceed the maximum levels or when prohibited substances are present. The Sale of Food Act (SOFA)/Food Regulations specify zero tolerance for residues and the AVA enforces action limits or internal MRLs in this context.

National action plan/strategy on AMU and AMR

Singapore has a National Strategic Action Plan on AMR which was developed by the One Health AMR Workgroup, comprised of representatives from four different agencies – the Ministry of Health, National Environmental Agency, Public Utilities Board (water agency) and the AVA. This workgroup has compiled data and coordinated efforts across animal, human, food and environmental sectors. It sets the framework for the national response to AMR and is aligned with the WHO Global Action Plan on AMR, with standards and guidelines established by FAO and OIE. It has five core strategies on education, surveillance and risk assessment, research, prevention and control of infection, and optimization of antimicrobial use.

There have been extensive education and awareness-raising exercises for fish farmers. As part of this plan, the AVA works with farms to promote and implement biosecurity and best practices to prevent and control disease outbreaks. Strict biosecurity requirements and good animal husbandry practices in accordance with national guidelines are required for farms, which are all licensed by the AVA. At the regional level, guidelines for good animal husbandry practices and GAPs have also been developed for poultry and aquaculture farms through the ASEAN Sectoral Working Group for Livestock and

2 Degree days are calculated by multiplying the average water temperature in degrees centigrade by the number of days following the end of treatment. A minimum of 500 degree days is the recommended withdrawal period indicated in the National Office of Animal Health (NOAH) Compendium.

Fisheries. The AVA will be looking into harmonizing the national GAP standards with the ASEAN guidelines in the near future.

The use of quality vaccines and alternatives to antimicrobials for the prevention of diseases is encouraged. The first commercial vaccine against Streptococcus iniaie for use in aquacultured finfish was licensed in 2005. This was followed by five more commercial vaccines from 2010 to 2017 against Streptococcus agalactiae and iridovirus; eight autogenous vaccines obtained conditional registration between 2014 and 2017. As of July 2018, there were 14 vaccines registered for aquaculture in Singapore (Table 3). There is increased use of vaccines by aquaculture farms to control diseases, including the use of autogenous vaccines for tropical fish pathogens.

Priority areas identified for further action include expanding the AMR surveillance programme to include all animal production sectors (including aquaculture) and promoting and facilitating the use of vaccines and alternatives to antimicrobials in fish.

Other national regulations pertaining to the supply, sale and use of antimicrobials

The AVA has licensing conditions for the manufacture of animal feed in place and has issued directives to farms for banning the use of certain antimicrobials in food-producing animals. At the same time, the AVA has a regular surveillance programme to detect antibiotic residues in market-size fish as part of its food safety programme. The AVA is in the process of strengthening legislation to regulate veterinary use of human therapeutic products, implementing a system of veterinary drug registration and requiring veterinary prescription for all veterinary antimicrobials, including those used in livestock and aquaculture. In addition, the legislation and conditions for the manufacture and use of autogenous vaccines have to be drafted as well.

Monitoring and surveillance of AMU and AMR

There is currently a surveillance programme focused on the antibiotics present and used on farms. In addition, AMR surveillance is based on antibiotic susceptibility testing in clinical fish samples submitted to the Aquatic Animal Health Laboratory, as part of regulatory disease surveillance, e.g. Vibrio spp. Generally, the AMR trend in clinical samples showed resistance toward ampicillin and amoxicillin/clavulanic acid. There is a need to enhance monitoring of AMU and AMR in aquaculture to link AMU and the emergence of AMR.

Strategy and actions in addressing AMR risks in aquaculture

To address AMR risks in aquaculture, Singapore will start by raising awareness on disease management and control in the aquaculture industry. Four objectives of the Aquatic Animal Health Plan help to achieve this:

- To understand the epidemiology of disease in farmed food fish in Singapore;
- To improve production by developing capacity in fish health management and fish welfare for farms;
- To ensure farms have access to diagnostic support, safe and effective therapeutic and biological treatments for farmed aquatic animals; and
- To strengthen farm biosecurity and aquatic animal disease emergency preparedness for Singapore.

Understanding the epidemiology of disease in farmed food fish in Singapore: To improve the productivity of food fish farms and improve health management of fish, it is important to first understand the epidemiology of any disease in farmed food fish. The review of the food fish surveillance programme recommended active surveillance on all farms for clinical and suspected subclinical cases of notifiable and nonnotifiable diseases of aquatic animals. Results from active and passive surveillance will help to form a three-dimensional disease map for the farms which will be both geographical (e.g. based on diseases identified from each farm production zone) and by species and life stages of fish. This will help to identify farms which require more diagnostic support. The disease map will be published online every quarter in the form of an Aquatic Animal Health Report. There will be guidelines for the identification, control and where applicable, treatment for the reported diseases included in the report. Surveillance results will also be used to formulate policies related to aquaculture, such as the drafting of policies on the use of medication and therapeutics in animals, the manufacture and use of autogenous vaccines in farmed animals, and review of the Animals and Birds Act.

Forming research collaborations with local institutions (e.g. James Cook University, and Temasek Polytechnic), as well as overseas institutions will allow the AVA to share surveillance data for analysis. This will provide understanding of disease epidemiology and transmission in local waters, and form measures to control diseases in farmed fish. A possible research project would be in aquaculture environmental surveillance, specifically on pathobiomes and on antimicrobial residues in sediments of the aquatic environment.

Developing capacity in fish health management and welfare for farms: The AVA will develop guidelines for a Health Management Plan for Food Fish Farms which will initially involve farms certified under Good Aquaculture Practices for Fish Farming (GAP-FF). The plan will outline treatment protocols for specific diseases encountered in farmed stock at each stage of production and the conditions under which the use of specific antimicrobials are permitted. The publication of surveillance findings in Aquatic Animal Health Reports will assist the farms in the development of their health plans.

Ensuring farms have access to safe and effective therapeutic and biological treatments as well as diagnostic support for farmed aquatic animals: The AVA is in the process of developing regulations for the manufacture and use of autogenous vaccines in Singapore. These would outline the roles and responsibilities of the farmers, veterinarians and vaccine manufacturers. Further consultation with stakeholders will be undertaken before these guidelines are finalized. Guidelines on prudent use of antimicrobials for the treatment of diseases of concern in farmed aquatic animals will also be formulated by veterinarians and fish health specialists in close collaboration with the private sector. In future, it will become mandatory for farms to obtain prescriptions for antimicrobials from veterinarians or aquatic animal health specialists before they can be used in any aquaculture operations. Surveillance of antimicrobial usage (both for animals and in feed) will be conducted on farms, eventually moving towards a regulated, self-declaration model. AMR and residues detected from Aquaculture Environmental Surveillance will also help to inform the development of these guidelines.

Using the disease map and AMR surveillance results, hot spots can be identified where direct intervention is required, such as mandatory vaccination of key food fish prestocking in open net cages. The long-term goal for 2035 is to achieve 100 percent vaccination of core diseases of concern for all food fish species stocked in semi-open and open systems. Laboratories will ensure that diagnostic capabilities are kept up to date by developing tests for key species of farmed fish and other aquatic animal species of economic importance.

Strengthening farm biosecurity and aquatic animal disease emergency preparedness for Singapore: The disease map will help inform the future free zone of specific disease policy and give an indication of the level and type of biosecurity required for farms in each zone. It may be necessary to implement disease-free measures zone-by-zone, which will require traceability and movement control steps. In line with the active investigations in notifiable diseases, a number of high priority, key diseases will be identified that will form the basis for an AVA-industry joint emergency preparedness contingency plan and agreement. The plan will reduce ambiguity on actions and implement mitigating measures for these high priority diseases which will have a profound impact on production and trade of aquatic animal products if left unchecked.

The licensing conditions for farms will be strengthened to manage aquatic animal health risks and fish health management will eventually be incorporated into farm licensing conditions. Licensing conditions will shift focus to having educated farmers employing a biosecurity and food safety plan akin to a Hazard Analysis and Critical Control Point (HACCP) on the farm, with the AVA playing a verification role.

Regional cooperation

The AVA will also work with ASEAN Member States to develop capacity in combating AMR in the aquaculture sector. For example, Singapore is currently securing funds to conduct laboratory training workshops for drug residues, as well as a risk analysis workshop for AMR in aquaculture in 2019. In subsequent years, these efforts will be further built on to assist ASEAN Member States to fulfil their national action plans for AMR.

Country case study 7 Assessment report on AMU and AMR risk in aquaculture in Viet Nam

Chuong Dinh Vo
Department of Animal Health, Ministry of Agriculture and Rural Development
Hanoi, Viet Nam

Introduction

With a rapid expansion in aquaculture areas and stocking densities, the Vietnamese aquaculture sector has been significantly influenced by disease outbreaks. Major diseases include WSD and AHPND in shrimps; Edwardsiella ictaluri and Aeromonas hydrophila infections in pangasius catfish; Streptococcus spp., A. hydrophila, Aeromonas spp. and Pseudomonas spp. infections in tilapia and indigenous fish. As a result, antimicrobials have played a critical role in the prevention and treatment of aquatic diseases. However, their imprudent use and overuse have been a contributing factor to the spread of AMR. AMR has been considered as one of the greatest threats to public health worldwide. FAO, OIE and WHO, collaborating in a Tripartite Agreement, identified AMR as one of the three priority topics for joint actions (FAO, OIE and WHO, 2012) and developed a Global Action Plan on AMR (WHO, 2015). In line with the One Health initiative, the Global Action Plan provides a framework for national action plans to combat AMR.

In Viet Nam, the Ministry of Health (MoH) initiated national activities to tackle AMR via the National Action Plan on Combatting Drug Resistance from 2013 to 2020 (MoH, 2013). The overall objective of the plan was to promote the prevention of drug resistance, thus contributing to enhanced quality and effectiveness of the prevention and control of epidemics, medical examination and treatment to protect, care for and improve people's health. It included six specific objectives, one of which was the promotion of proper AMU in livestock, poultry, aquaculture and cultivation. In 2017, the Ministry of Agriculture and Rural Development (MARD) issued Decision No. 2625/QĐ-BNN-TY dated 21 June 2017 on the 'National Action Plan (NAP) for Controlling AMU & AMR in Livestock Production and Aquaculture (2017-2020)'. The main objective was to mitigate the risk of antibiotic resistance in public health by controlling AMU in livestock production and aquaculture (MARD, 2017b). Major activities of the NAP are: (1) strengthen and consolidate the state management of AMU and AMR; (2) improve the legal basis for AMU and AMR management; (3) enforce regulations and technical guidelines; (4) increase awareness of AMU and the risks of AMR; (5) implement good treatment and husbandry practices in livestock feed manufacturing and livestock production and aquaculture; (6) monitor AMU, AMR and antibiotic residues; and (7) strengthen intersectoral collaboration in AMR management.

From 2011 to 2017, several pilot surveys were carried out by government agencies, universities and international organizations on the major aquaculture species in Viet Nam including pangasius catfish, brackishwater shrimp, freshwater shrimp, tilapia and indigenous freshwater fish to better understand the status of AMU and AMR.

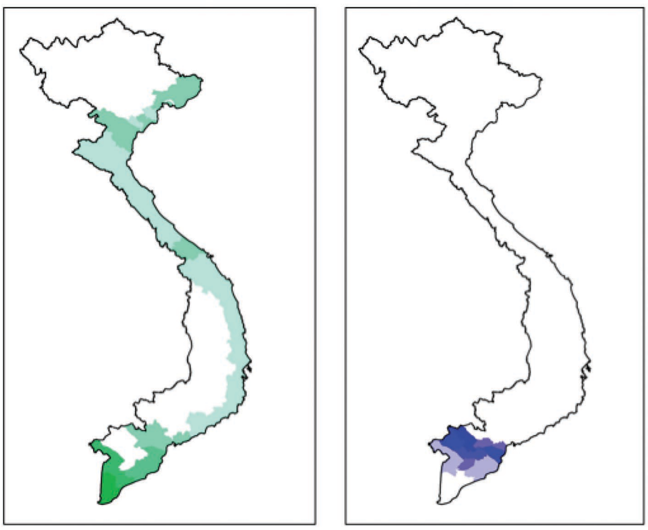
This assessment report was sponsored by FAO–RAP and NACA to assess AMU and AMR in aquaculture in the Vietnamese context. The status of aquaculture, AMU and initial results on AMR as well as progress on the aquaculture component of the Vietnamese National Action Plan for AMR are presented.

The aquaculture industry in Viet Nam and major disease problems

Aquaculture plays an important role in the agriculture sector and contributes significantly to Viet Nam's economy; more importantly, it creates jobs and livelihoods for many farmers. Brackishwater shrimps and pangasius catfish are the two major cultured species , mainly for export. Currently, Viet Nam has 30 shrimp-farming provinces (Figure 1), with black tiger shrimp (Penaeus monodon) and white leg shrimp (Litopenaeus vannamei) as the two dominant cultured species. Pangasius catfish are cultivated intensively in ten provinces in the Mekong River Delta (Figure 1). In addition, tilapia, indigenous freshwater fish, marine fish and lobsters are also important to the national aquaculture industry. The shared production of the main aquaculture groups in 2016 is shown in Table 1.

Brackishwater shrimp aquaculture: Brackishwater shrimps are cultivated in 30 coastal and Mekong Delta River provinces, of which Ca Mau, Bac Lieu and Soc Trang are the three most intensively cultured provinces. In 2017, the total area of shrimp farming was 720 000 ha with 621 000 ha for P. monodon and 99 000 ha for L. vannamei (D-Fish, 2018). The culture systems of shrimps are diverse consisting of intensive farming, semi-intensive farming, extensive

Figure 1. The main inland aquaculture area in Viet Nam; 30 provinces produce brackishwater shrimps (left) and 10 provinces produce pangasius (right)



Source: Aquatic Animal Health Division, DAH.

Table 1. Shares of production by major groups of cultured aquatic organisms in 2015

Major farming groups	Production (tonnes)	Percent of production
Pangasius catfish	1 221 000	34.6
Tilapia	187 800	5.3
Shrimps	595 900	18.9
Marine fish	90 000	2.5
Clams	254 500	7.2
Seaweed	10 000	0.3
Others (carps, prawns)	1 156 000	32.7

Source: Tuan, 2016.

farming, improved extensive farming, rice–shrimp farming and mangrove–shrimp farming. Recently, the focus has been on intensive and semi-intensive farming (Figure 2) to increase production and quality of shrimp products to meet the requirements of importing countries.

The total production of brackishwater shrimp in 2017 was 689 000 tonnes, of which P. monodon accounted for 258 500 tonnes and L. vannamei 430 500 tonnes. The total revenue from exported shrimps in 2017 exceeded USD 3.85 billion. Vietnamese shrimps are exported to 99 countries and territories, of which the EU, Japan, the People's Republic of China, the United States and Republic of Korea are the major markets accounting for 83.5 percent of the total shrimp export value of Viet Nam.

Figure 2. Intensive grow-out pond of brackishwater shrimp in Bac Lieu Province

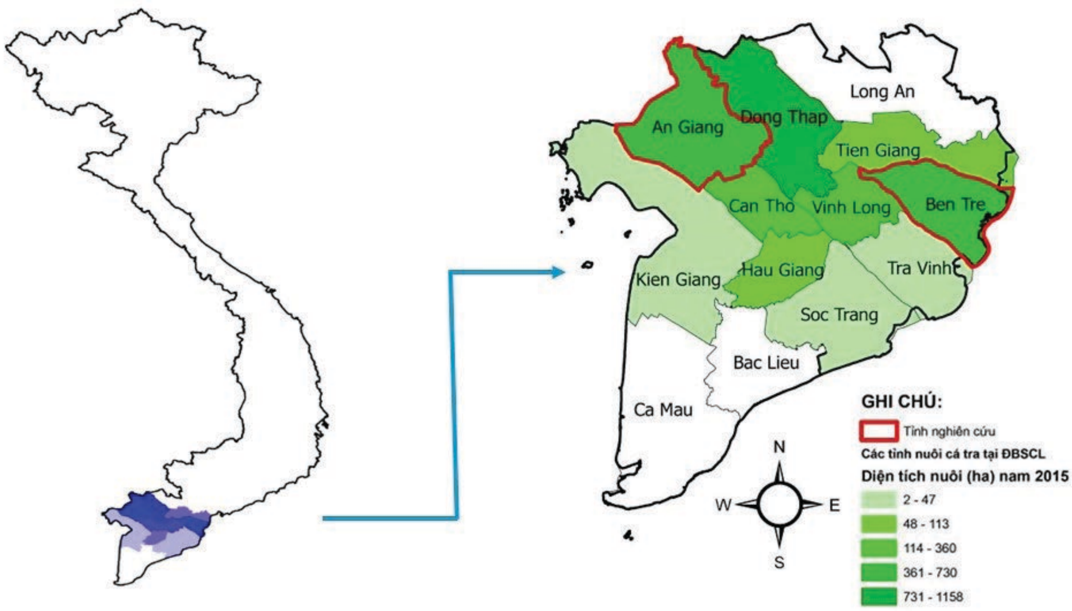
©Aquatic Animal Health Division-DAH.

Diseases cause significant losses in the Vietnamese shrimp aquaculture industry annually. WSD and AHPND are the two most common diseases in brackishwater shrimp. AHPND began to impact this industry in 2012 and caused huge damage for almost the whole shrimp farming sector nationwide. These two diseases affect both P. monodon and P. vannamei from 20 to 60 days poststocking and occur almost every month during farming seasons (MARD, 2017a).

In 2015, WSD occurred over 5 237 ha, accounting for 0.77 percent of cultured areas, while in 2016, the disease occurred over 3 643 ha (0.54 percent). In 2017, the total area affected by WSD was 5 020 ha. In comparison with WSD, AHPND caused heavier impact on farmers. In 2015, the disease affected 9 284 ha accounting for 1.37 percent of farmed areas. In 2016, the total affected area was 6 032.68 ha (0.9 percent, a decrease of 35.96 percent compared to 2015). In 2017, the total area affected was 6 793 ha. The disease was limited to small-scale farms with low investment, inadequate farming conditions and low levels of biosecurity practices, and rarely occurred in intensive and high-tech farms.

Pangasius catfish aquaculture: Pangasius are cultured intensively in Dong Thap, An Giang, Ben Tre, Can Tho, Tien Giang, Vinh Long, Hau Giang, Soc Trang, Kien Giang and Tra Vinh provinces in the Mekong River Delta (Figure 3). The common method for pangasius farming is closed systems in earthen ponds. There are two main farming types – commercial and breeding modes (fattening of broodstock, breeding and nursing of seedlings). Pangasius production is divided into three main types (2012 data): farms owned by farmers (1 748.4 ha, 48.7 percent); farms owned by enterprises/companies (1 761.6 ha, 49.1 percent); and farms belonging to cooperatives (77.3 ha, 2.2 percent). By 2013, household farming had dropped to 35.5 percent, while enterprises and cooperatives had increased to 59.9 percent and 4.6 percent respectively (VNAP, 2016).

Figure 3. Locations of ten key pangasius catfish-farming provinces in Viet Nam



Source: Aquatic Animal Health Division, DAH.

Pangasius farming area, production and export value increased continuously from 2001 to 2009 (Table 2), i.e. from 2 317 ha to 6 022 ha (farming area), 46 000 tonnes to 1 090 000 tonnes (production) and USD 6 million to USD 1.34 billion (export value). From 2010 to 2017, farming area and production remained stable at around 5 000 ha and 1 100 million tonnes, with export value ranging from USD 1.4 to USD 1.8 billion.

Diseases in pangasius appear from stocking to the end of the farming season, with losses ranging from 10 percent to 25 percent in the main culture season, especially from January to July. Common diseases in pangasius are enteric septicaemia of catfish (ESC) caused by Edwardsiella ictaluri, haemorrhagic septicaemia caused by Aeromonas hydrophila, yellow disease and white gill disease, of which the most common and damaging diseases are ESC and haemorrhagic septicaemia.

Table 2. Pangasius farming and export value in Viet Nam from 2001 to 2015

Year	Farming area (ha)	Production (million tonnes)	Export value (million USD)
2001	2 317	46	6
2002	2 413	91	87
2003	2 792	133	82
2004	3 325	210	229
2005	4 913	371	328
2006	3 653	406	737
2007	5 430	683	979
2008	5 973	1 198	1 453
2009	6 022	1 090	1 343
2010	5 420	1 141	1 428
2011	5 427	1 195	1 805
2012	5 911	1 286	1 744
2013	5 556	1 131	1 760
2014	5 500	1 047	1 768
2015	5 055	1 027	1 565
2016	5 050	1 150	1 710
2017	5 227	1 250	1 785

Source: Ministry of Agriculture and Rural Development.

Tilapia aquaculture: Tilapia is becoming one of the most important cultured species in Viet Nam after brackishwater shrimps and pangasius. Tilapia is cultured in regions from north to south, but most farms are located in the Northern Delta and Mekong Delta regions covering an area of 10 660 ha. Oreochromis niloticus, hybrid tilapia (O. niloticus × O. aureus) and red tilapia (Oreochromis spp.) are the most popular species for farming. Typical tilapia culture in Viet Nam includes both polyculture and monoculture. For the polyculture model, tilapia is cultured with indigenous fish such as common carp, silver carp, grass carp or brackishwater shrimp. For monoculture, tilapia is cultivated in earthen ponds or cages in the rivers. Stocking density for pond culture is 15 fish/m2 to 20 fish/m2 while for cage farming it is 80 fish/m2 to 100 fish/m3. The average production for intensive farming in ponds is from 6 tonnes/ha to 7 tonnes/ha while for cage culture it is 40 kg/m3 to 80 kg/m3 (RIA1, 2017). The total farming area for tilapia in 2016 was about 25 000 ha with production of around 200 000 tonnes (Table 3). In 2015, Vietnamese tilapia was exported to more than 60 countries and territories all over the world and the export value was approximately USD 27.5 million.

Table 3. Farming area and production of tilapia of Viet Nam, 2016.

Farming region	Farming area (ha)	Production (tonnes)
Northern Mountainous	7,348	11,806
Northern Delta	10,660	69,548
North Central	2,400	11,600
South Central	512	3,800
Highlands	1,578	1,911
South East	1,027	5,325
South West	1,648	90,841
Total	**25,173**	**194,831**

Source: D-Fish, 2016a.

The demand for tilapia seeds in Viet Nam is quite high at around 650 million fry/fingerlings per year. The capacity of 236 hatcheries, however, can only provide around 70 percent of the demand and the rest is imported. Aside from this shortage in seed supply, the Vietnamese tilapia industry also faces other challenges including lack of planning for tilapia aquaculture, diseases, and low and unstable markets and price.

In a polyculture system with tilapia and indigenous fish, tilapia are susceptible to many pathogens, especially at sizes below 100 g. Tilapia become more sensitive to disease when the weather changes or when new species are introduced, due to transportation stress and damage or environmental shock. The common pathogens are *Trichodina* sp., *Myxobolus* sp., *Achlya* sp., *Aeromonas hydrophila and Streptococcus* spp. *(S. agalactiae and S. iniae).* In a culture system with tilapia and shrimps, Streptococcus spp. is the most common pathogen. For monoculture, tilapia are often infected with *Edwardsiella tarda, Streptococcus* spp. and Aeromonas spp., especially *Streptococcus agalactiae* and *Aeromonas hydrophila* (RIA1, 2017).

Marine aquaculture: Viet Nam has a coastline that extends for 3 260 km with high potential for marine farming areas including closed gulfs, coastal intertidal zones, islands and open sea area. Viet Nam's total potential area for marine culture is approximately 244 190 ha. Coastal intertidal farming areas comprise 153 300 ha (62 percent), farming areas in gulfs and islands account for 79 790 ha (33 percent) and farming areas on open sea constitute 11 100 ha (5 percent) of the total marine farming area (D-Fish, 2016b). Currently, marine aquaculture is focused on species such as marine fish, lobster, crab, molluscs and seaweed. Marine fish species include grouper, cobia, pilot fish, *Sparidae, Sciaenops ocellatus,* barramundi and snub-nose pompano. Grouper, cobia and barramundi are the most popular species for culture.

Marine finfish: The most common marine fish cultured in Viet Nam are grouper, cobia, Japanese amberjack (yellow tail), mangrove snapper, red seabream, red snapper, sea bass, mullet and snub-nose pompano. Marine fish are cultivated mainly in Quang Ninh (north), Khanh Hoa, Ba Ria Vung Tau (central) and Kien Giang (south) provinces. Fish are farmed in earthen ponds near the sea and in open sea cages. In 2017, the total pond farming area was 5 166 ha while the area for open sea cages (180 200 cages) was around 1 093 863 m3, with production of 29 770 tonnes (D-Fish, 2018)

There are 32 breeding farms for marine fish with yield of 30 million seeds per year. The hatcheries are mainly located in Quang Ninh, Hai Phong and Khanh Hoa provinces which produce cobia, grouper, seabass and red snapper seeds.

Molluscs: The cultured area for molluscs increased from 25 560 ha in 2010 to 41 200 ha by 2017 with production of 135 011 tonnes and 272 832 tonnes, respectively (Table 4). Cultured species include hard clam, Pacific oyster, sweet snail, snout otter clam, scallop, blood cockle/granular ark, and green mussel. Molluscs are mainly raised in the north and north central regions (Hai Phong, Thai Binh, Nam Dinh, Ninh Binh, Thanh Hoa provinces) and in the south (Tien Giang, Ben Tre and Tra Vinh provinces).

There are 465 mollusc hatcheries with production of about 30 billion seeds per year, but this only meets 50 percent of the demand for seedlings. The hatcheries are mainly located in Quang Ninh (otter clam, oyster), Nam Dinh (hard clam), Khanh Hoa, Ninh Thuan, Ben Tre, Tien Giang (sweet snail).

Vietnamese mollusc products (mainly hard clams, scallop and snail) are exported to 42 countries including the EU, the United States, Spain and Portugal. Export value increased from USD 57 million in 2010 to USD 95 million in 2017. In 2013, the EU recognized 12 mollusc-farming regions in Viet Nam that meet food safety conditions (D-Fish, 2016b).

Table 4. Culture status and production of the major mollusc species in Viet Nam

Indicator/species	Unit	2010	2012	2015	2017
1. Farming area	**ha**	**25 560**	**30 936**	**40 685**	41 200
Clam	ha	14 760	18 532	18 720	19 083
Oyster	ha	1 325	1 828	2 465	2 100
Sweet snail	ha	451	607	990	1 017
Geo-duck/otter clam	ha	580	454	81	19 000
Scallop	ha	7 630	8 111	11 440	
Other species	ha	814	1 404	6 989	

Indicator/species	Unit	2010	2012	2015	2017
2. Production	**tonnes**	**135 011**	**196 689**	**265 310**	**272 832**
Clam	tonnes	109 250	160 000	186 910	179 183
Oyster	tonnes	5 400	9 012	11 965	8 303
Sweet snail	tonnes	1 211	2 064	4 303	5 433
Geo-duck/otter clam	tonnes	747	531	155	79 913
Scallop	tonnes	17 527	23 200	48 330	
Other species	tonnes	876	1 882	13 647	
3. Productivity	**tonnes/ha**	**5.28**	**6.36**	**6.52**	**6.6**
4. Export value	Million USD	**57.00**	**68.00**	**82.39**	**95**

Source: Vietnam Association of Seafood Exporters and Producers (VASEP).

Lobsters: Lobsters are mainly cultured in coastline provinces of the central region with Phu Yen and Khanh Hoa as the two key farming provinces. *Panulirus ornatus* and *P. homarus* are the two major cultured species. There are several systems for farming of lobsters, such as fixed cages, submerged cages or earthen ponds, but the most common system is culture in floating cages.

The floating cages are either square or rectangular of between 2.8 m×2.8 m and 4.0 m×4.0 m (most commonly used); the cage frame is typically made from bamboo or solid timber; floats can either be reused plastic drums of about 200 litres or smaller plastic cans of 20 litres. In 2017, there were 66 237 floating cages with production of around 1 530 tonnes, creating turnover for the farmers of above USD 160 million/year. The provinces of Phu Yen (production > 486 tonnes) and Khanh Hoa (production > 500 tonnes) accounted for more than 90 percent of national lobster production.

Lobster farming in Viet Nam faces constraints such as diseases, mortality of puerulus caught in the wild, reliance on trash fish feed and planning of cage culture sites. The common diseases of cultured lobsters are milky disease, red-body disease, black gill disease, big head syndrome and separate head syndrome. Of these, milky disease causes the most significant production losses (approximately 50 percent between 2007 and 2009). Approximately 50 percent of total production was lost to milky disease. Measures to mitigate milky disease have been implemented by the government but with limited success (Jones and Tuan, 2016).

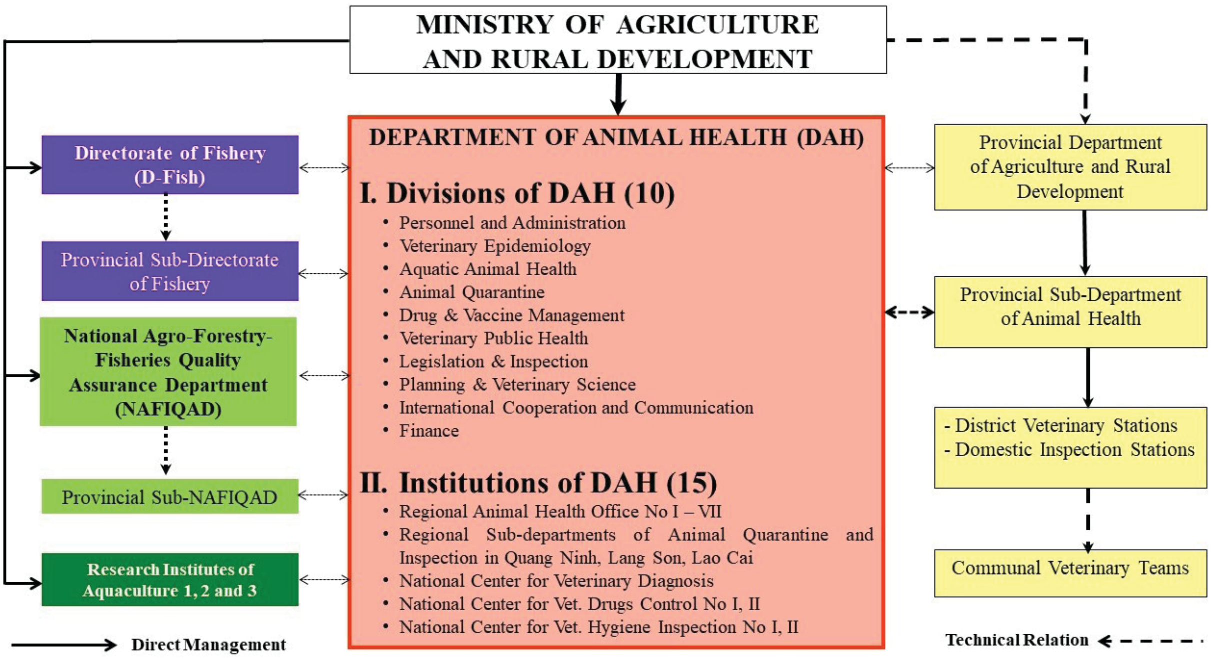
Agencies responsible for regulation and monitoring of AMU and AMR in aquaculture in Viet Nam

MARD is responsible for setting out legislation on AMU and AMR in livestock and aquaculture production including: (i) national technical regulation of veterinary medicines; (ii) lists of veterinary medicines permitted for circulation in Viet Nam; (iii) lists of veterinary medicines banned for use in Viet Nam; and (iv) provisions on content labelling, testing records, production, sale, import and circulation of veterinary drugs.

The Department of Animal Health (DAH) has responsibilities for drafting/developing regulations on AMU and AMR in livestock production and aquaculture. The DAH also develops technical guidance on AMU and AMR in livestock and aquaculture.

The DAH also has responsibilities for monitoring of AMU and AMR in aquaculture, including importation, registration and circulation of antibiotics. It is also responsible for implementing and monitoring AMU and AMR in livestock and aquaculture at the national level. The National Agro-Forestry and Fishery Quality Assurance Department (NAFIQAD) is running a national monitoring programme for chemical and antibiotic residues of aquatic animal products. At the provincial level, implementation is delegated to provincial subDAH, subD-Fish and subNAFIQAD offices (Figure 4).

Figure 4. Organizational structure of veterinary services at central and local levels in Viet Nam



Source: Department of Animal Health.

Monitoring of AMU in aquaculture in Viet Nam

From 2011 to 2017, several pilot surveys on AMU and AMR were carried out by government agencies, universities and international organizations for the major aquaculture species including pangasius catfish, brackishwater shrimp, freshwater shrimp, tilapia and indigenous freshwater fish.

AMU in freshwater shrimp and fish in 2011: A survey on AMU in freshwater shrimp and fish was carried out by the Vietnam National University of Agriculture and Oxford University from July to August 2011 among 94 households in the Red River Delta (Hai Duong and Hanoi: 48 households) and Mekong River Delta (Dong Thap and Can Tho provinces: 46 households) (Ton et al., 2011).

Results showed that 72.34 percent of the households used antibiotics during their production cycle, mostly for prevention and treatment of diseases at nursery and breeding farms, rather than at the grow-out farms (Table 5). The survey showed that to produce 1 tonne of commercial fish or shrimp, the average amount of antibiotics used was about 2.41 kg or 18.50 kg/ha.

Table 5. Quantity and purpose of using antibiotics in surveyed households

Monitoring indicators		**Red River Delta**		**Mekong River Delta**	**Total (n = 94)**
		Fish (n = 41)	Shrimp (n = 7)	Fish (n = 22)	Shrimp (n = 24)
Households using antibiotics (%)		70.73	85.71	59.09	72.34
Purpose	Control of diseases	75.61	100.0	68.18	67.02
	Prevention of diseases	9.76	0.0	4.55	5.32
Amount used (kg/tonne fish or shrimp)		3.13	1.23	1.38	2.41
Amount used (kg/ha)		19.19	6.51	37.40	18.50

Source: Ton *et al.*, 2011.

Abuse in AMU was indicated via the number of antibiotics that the farmers used in a production cycle. At least 24 antibiotics belonging to more than 10 different groups were used in freshwater shrimp (9 types of antibiotics) and fish culture (23 types of antibiotics). Most of the antibiotic products in the market consisted of at least two active ingredients. To prevent and control diseases in shrimp or fish, farmers commonly used one to seven different antibiotics. Tetracycline, sulphamide and (fluoro)quinolones were the most widely used.

Typically, antibiotics were mixed with feed and the farmers often used antibiotics at higher (37 percent on average) dosages than those recommended by the manufacturers. Farmers' knowledge about the use of antibiotics and the effects of abuse was very limited. Selection of antibiotics was based mainly on experience and sometimes upon consultation with veterinarians, drug sellers, extension workers or other households. More households (30.90 percent) agreed about the use of antibiotics for disease prevention while only 5.30 percent thought otherwise.

AMU in brackishwater shrimp (2015): In 2015, the DAH conducted a pilot survey on AMU in 218 small-scale grow-out farms of shrimp in Hoa Binh District and Bac Lieu City of Bac Lieu Province. The results showed that 146 farms (67 percent) used antibiotics during the production cycle. Antibiotics were used mainly for disease prevention (61.60 percent), for both prevention and treatment (14.40 percent), and for disease treatment alone (24 percent).

AMU in pangasius catfish (2015): To understand the actual situation of farming, diseases and AMU in pangasius catfish farmed in three key farming provinces (An Giang, Dong Thap and Ben Tre), the DAH in cooperation with local agencies undertook a survey in selected districts with a total of 272 farms (mostly small-scale farms, including 139 grow-out farms and 133 nurseries and hatcheries) in November 2015. The results are described hereunder:

Grow-out farms. A total of 139 grow-out farms in the three provinces was investigated, most of which were small scale. Around 83 percent of the farms used antibiotics for prevention (24 percent) and treatment (75 percent) of diseases. Only 38 percent of farms used antibiotic sensitivity testing prior to antibiotic use (Table 6). Approximately 50 percent of the surveyed farms used florfenicol, amoxicillin, doxycycline, trimethoprim, sulphamethoxazole and tetracycline. Antibiotics were mixed with pellet feed before feeding to the fish. The dosages of antibiotics were estimated based on the body weight of fish and the recommended dosage of the manufacturers, while some farmers based the dosage on their previous experience.

Table 6. Summary of survey results at grow-out farms of the three provinces

Parameters	An Giang		Ben Tre		Dong Thap		Total	
	No. of farms	%	No. of farms	%	No. of farms	%	No. of farms	%
Total farms surveyed	68		21		50		139	
Farms using antibiotics	**56**	**82.35**	**17**	**80.95**	**42**	**84.00**	**115**	**82.73**
Disease treatment	51	91.07	16	94.12	20	47.62	87	75.65
Disease prevention	5	8.93	1	5.88	22	52.38	28	24.35
Sensitivity testing	3	5.36	14	82.35	26	61.90	43	37.39

Source: Department of Animal Health.

Hatcheries and nursery farms: A total of 133 farms, mostly small scale, (An Giang Province, 52 farms; Dong Thap Province, 81 farms) including 109 nurseries, 9 hatcheries and 15 nursery and hatchery combinations were investigated, of which 76 percent were using antibiotics, mostly without prior antibiotic sensitivity testing. Farmers often used antibiotics to combat pathogens and about 40 percent of the farms used antibiotics for disease prevention or for both prevention and treatment. The commonly used antibiotics were amoxicillin, florfenicol, doxycycline and tetracycline (Table 7). Antibiotics were administered through feed with the dosages estimated based on fish body weight as recommended by the manufacturers.

Table 7. Summary of survey results at nurseries and hatcheries in An Giang and Dong Thap provinces

Parameter	An Giang		Dong Thap		Total	
	No. of farms	%	No. of farms	%	No. of farms	%
Total farms surveyed	52		81		**133**	
Farms using antibiotics	**36**	**69.23**	**65**	**80.25**	**101**	**75.94**
For disease prevention	0	-	10	15.38	10	9.90
For disease treatment	36	100.00	25	38.46	61	60.40
For both prevention and treatment	0	-	32	49.23	32	31.68

Source: Department of Animal Health.

Aside from antibiotics, other chemicals were often used in hatchery stages for farming tool disinfection and pond/tank preparation including iodine, chlorine, Virkon® S, KMnO4, yucca, TCCA, CuSO4, NaCl and lime.

AMU in pangasius catfish (2017): In August 2017, the DAH and NACA, in coordination with provincial subDAH offices in An Giang, Dong Thap and Can Tho provinces carried out a survey on disease status and AMU in pangasius culture. A total of 76 farms (including 2 hatcheries, 13 nurseries and 61 grow-out farms) was surveyed.

Antibiotics were used widely (66/76 farms or 86.84 percent) with different commercial names and ingredients. As nurseries are very sensitive to many diseases and often suffer huge losses, farmers had to use various antibiotics to prevent disease outbreaks. Conversely, no antibiotics were used in hatcheries as fish larvae are maintained for a very short period (less than 24 hours posthatching) before retail to nursery farms.

In general, farmers did not require a veterinary prescription to purchase antibiotics and were often advised to use them by drug dealers.

Farmers used 12 antibiotics to treat diseases in pangasius catfish (Table 8) of which amoxicillin, doxycycline and florfenicol predominated at 56.06, 46.97 and 43.94 percent, respectively.

Table 8. Antibiotics used at investigated pangasius farms

Antibiotics	No. of farms	Proportion (%)
Amoxicillin	37	56.06
Doxycycline	31	46.97
Florfenicol	29	43.94

Antibiotics	No. of farms	Proportion (%)
Trimethoprim	16	24.24
Levomycine	12	18.18
Cephalexin	11	16.67
Sulphamethoxazol	9	13.64
Tetracycline	7	10.61
Oxytetracycline	6	09.09
Ampicillin	5	07.58
Kanamycine	2	03.03
Gentamycine	2	03.03

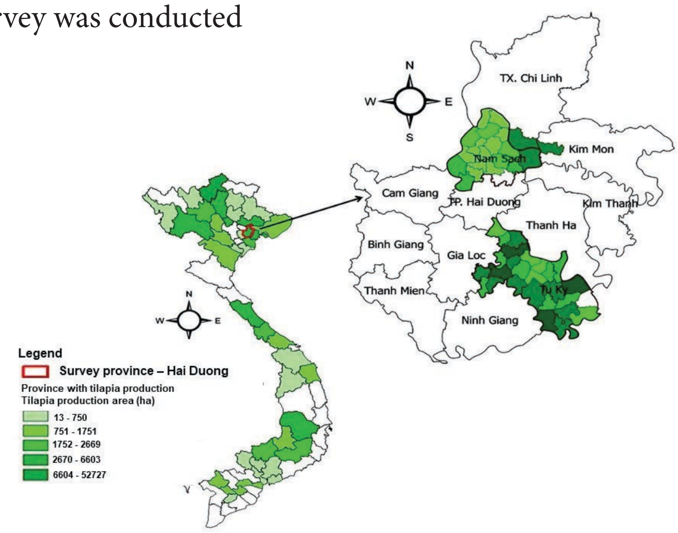
Source: Department of Animal Health.

The duration of antibiotic treatment for pangasius depended on individual farms but ranged from 1 to 7 days but the most common treatment duration was 3 days (13/66 farms). More often, if the severity of disease decreased during treatment, farmers would stop using antibiotics as an economy measure; if treatment was not effective, the diseased fish would be starved for two to three days and environmental treatment or change to other antibiotics would be applied.

For antibiotic dosage, most farmers depended on the instructions of the drug sellers for farm application of the drugs, thus there were no records of exact dosages. Some farmers treated diseases by themselves based on their own experience.

AMU in tilapia and indigenous fish in Hai Duong Province: This survey was carried out by the DAH and Research Institute for Aquaculture No. 1 (RIA1) in 2017 and funded by the FAO/FMM/RAS/298 project in 60 small-scale households. The objective was to assess the status of AMU/AMR for prevention and control of diseases in tilapia and indigenous fishes in two districts of Hai Duong Province (Figure 5). The results on farmers' awareness, common practices in using antibiotics and AMR status for *A. hydrophila* and *Streptococcus* sp. are summarized below.

Figure 5. Map of Nam Sach and Tu Ky districts in Hai Duong Province (red square) where the AMU and AMR survey was conducted



Source: Department of Animal Health.

In terms of farmers' knowledge about antibiotics, although 95 percent of the surveyed household owners said that they could detect signs of diseases, only 30 percent asked for technical advice on treatment; 75 percent of the farmers used antibiotics during the production cycle. Importantly, 65 percent of the households said that they used a higher dosage of antibiotics than that recommended by the manufacturers. About 13.30 percent of the households believed that antibiotics could be used to treat viral diseases, 65 percent said that they could be used to treat bacterial diseases and at least 16.70 percent said that they used antibiotics for growth promotion. Most farmers used antibiotics through feed incorporation.

Isolation of targeted pathogens (Streptococcus sp. and Aeromonas hydrophila) was done from 177 fish samples for AMR analysis. Only two fish samples were found positive for Streptococcus sp. but six samples for A. hydrophila. Fourteen antibiotics were used for analysis of Streptococcus spp.: ampicillin (10 µg), doxycycline (30 µg), novobiocin (5 µg), neomycin (30 µg), rifampicin (30 µg), florphenicol (30 µg), chloramphenicol (30 µg), trimetjoprim/sulphamethoxazole (1.25/23.75 µg), ciprofloxacin (5 µg), oxacillin (1 µg), erythromycin (15 µg), streptomycin (10 µg), tetracycline (30 µg) and vancomycin (30 µg). Thirteen antibiotics were used for A. hydrophila: doxycycline (30 µg), novobiocin (5 µg), neomycin (30 µg), rifampicin (30 µg), trimetjoprim/sulphamethoxazole (1.25/23.75 µg), florphenicol (30 µg), chloramphenicol (30 µg), ciprofloxacin (5 µg), oxacillin (1 µg), erythromycin (30 µg), streptomycin (10 µg), tetracycline (30 µg) and vancomycin (30 µg).

A total of 20 A. hydrophila strains (6 strains from this survey and 14 other strains from tilapia and indigenous fish in previous years) and 8 Streptococcus spp. strains (two strains from this survey and 6 other strains from tilapia in previous years) were tested for AMR. The results showed that of the nonwild type strains, 45 percent of the tested A. hydrophila strains responded to ciprofloxacin, 35 percent to trimethoprim/sulphamethoxazole, 20 percent to tetracycline and chloramphenicol, 15 percent to erythromycin and doxycycline, 10 percent to florphenicol and 5 percent to rifampicin. Disc diffusion-based cut-off values for wild type A. hydrophila strains was: ≥ 11 mm for florphenicol, ≥ 12 mm for erythromycin, ≥ 14 mm for rifampicin and neomycin, ≥ 18 mm for doxycycline, ≥ 19 mm for tetracycline and trimethoprim/sulphamethoxazole, ≥ 25 mm for chloramphenicol and ≥ 34 mm for ciprofloxacin. There was no AMR data analysis for Streptococcus spp. strains.

Potential AMR risks related to aquaculture in Viet Nam

There are various potential risks for the development of AMR, of which the risks originating from public health, agriculture and livestock production are obvious. AMR could develop due to improper practices among public health and agriculture sectors such as the improper use of antibiotics (overdosing, suboptimal dosing or antibiotic abuse). These conditions facilitate favourable environments for drug-resistant micro-organisms to occur and spread. Quality assurance and control systems do not meet actual demand and are unable to assure the quality of different drugs/medicine available in the market. Ineffective prevention and control of infectious diseases in humans and animals has led to the spread of AMR bacteria. Patients and sick animals serve as potential sources to transmit resisted pathogens to other people, animals and the environment.

AMR could arise from livestock production and aquaculture activities owing to:

- Inadequate regulations on the management of antibiotic use for treatment, prevention and control of diseases, growth promotion, control of bacterial contamination, and control of the spread of drug-resistant bacteria in livestock production and aquaculture;
- Weak enforcement of laws;
- A surveillance system for AMR in livestock production and aquaculture has not been established; AMR surveillance has been carried out only in some pilot research projects;
- Lack of linkage between the antibiotics surveillance systems in human health care and agriculture;
- Inadequate capacity of laboratories to identify resistant micro-organisms, which has constrained the detection of newly emerging resistant micro-organisms;
- Antibiotic abuse in disease prevention and control in livestock production and aquaculture as well as in growth promotion. Limited awareness on AMU and AMR among both professionals and fish farmers; and
- Antibiotics are sold widely without veterinarians' prescriptions.

Viet Nam's regulations related to AMU and AMR in livestock production and aquaculture

The legal basis for AMU and AMR in livestock production and aquaculture includes:

- The Law on Pharmacy No. 105/2016/QH13 dated 6 April 2016.
- The Law on Prevention and Control of Infectious Diseases No. 03/2007/QH12 dated 21 November 2007.
- The Law on Veterinary No. 79/2015/QH13 dated 19 June 2015.
- The Law on Fisheries No. 18/2017/QH14 dated 21 November 2017.
- Decision No. 2174/QĐ-BYT dated 21 June 2013 by the Minister of Health approving the National Action Plan against Drug Resistance.
- Decision No. 5888/QĐ-BYT dated 10 October 2016 on the establishment of the National Steering Committee on the prevention of AMR for the period 2016-2020.
- Decision No. 2888/QĐ-BYT dated 5 August 2014 on the establishment of 9 Sub-committees on drug resistance surveillance.
- Circular No. 04/2016/TT-BNNPTNT dated 10 May 2016 regulating the prevention and control of fisheries diseases.
- Circular No. 07/2016/TT-BNNPTNT dated 31 May 2016 regulating the prevention and control of terrestrial animal diseases.

- Circular No. 09/2016/TT-BNNPTNT dated 1 June 2016 regulating the control of slaughtering and examination of veterinary hygiene.
- Circular No. 13/2016/TT-BNNPTNT dated 2 June 2016 regulating veterinary drug management.
- Circular No. 26/2016/TT-BNNPTNT dated 30 June 2016 regulating the quarantine of animals and fisheries products.
- Circular No. 25/2016/TT-BNNPTNT dated 30 June 2016 regulating the quarantine of terrestrial animals and terrestrial animal products.
- Circular No. 10/2016/TT-BNNPTNT dated 1 June 2016 issuing the list of veterinary medicines approved for circulation in Viet Nam and list of chemicals and antibiotics prohibited for use in aquaculture in Viet Nam.
- Circular No. 24/2017/TT-BNNPTNT dated 15 November 2017 laying down the Table of HS Code for specialized goods import and export under the man agement of MARD.
- Decision No. 2803/QĐ-BNN-TY dated 7 July 2016 developed by the MARD on the issuance of a 'Plan for management and supervision of imported antibiotic materials for production of veterinary medicine during 2016-2020 period'.
- Decision No. 2625/QĐ-BNN-TY dated 21 June 2017 of MARD approval of 'National Action Plan for management of antibiotics use and control of antibiotics resistance in livestock production and aquaculture in the period of 2017 – 2020'.

Regarding regulations on veterinary medicine use in livestock production and aquaculture, Article 104 of the Veterinary Law regulates the use of veterinary medicines, as well as the rights and obligations of organizations, individuals as follows:

Veterinary medicines must be used according to the manufacturer's instructions, i.e. the prescriptions for individuals conducting veterinary practices under specialized management by veterinary agencies.

Organizations and individuals using veterinary drugs have the following rights: (i) to be provided with information and guidance on how to use veterinary drugs; (ii) to request establishments selling veterinary drugs to provide guidance on veterinary drug use; (iii) to be paid compensation for any damage caused by the purveyor of veterinary drugs as prescribed by law.

Organizations and individuals using veterinary medicines have the following obligations: (i) use veterinary drugs under provisions of this law; (ii) upon detection of veterinary medicines causing harm to animals, the environment and human health, to stop using the drug and immediately report to commune-level People's Committees or the local specialized veterinary agency.

The Fishery Law in 2017 also regulates the principles of using antibiotics in aquaculture. In particular, Article 7 states that it is illegal to use antibiotics and veterinary medicines that are banned in aquaculture.

Circular No. 13/2016/TT-BNNPTNT dated 2 June 2016 of MARD regulates veterinary management and all aspects of veterinary medicine use.

To enhance state management on importation of antibiotics, especially antibiotic materials, on 7 July 2016, the Minister of MARD issued Decision No. 2803/QĐ-BNN-TY on the issuance of a 'Plan for management and supervision of imported antibiotic materials for production of veterinary medicine during 2016-2020'.

Contributing to the global campaign to mitigate AMR development, on 21 June 2017, the Minister of MARD issued Decision No. 2625/QĐ-BNN-TY approving the 'National Action Plan on management of antibiotics use and combating antibiotics resistance in livestock production and aquaculture in the period of 2017-2020'. Several initial activities on the aquaculture component with reference to the four pillars of the FAO Action Plan on AMR (awareness-raising, good governance, developing evidence-based guidelines and following best practices) have been carried out, including the establishment of a National Steering Committee for the prevention and control of aquatic animal diseases, AMU and AMR in aquaculture. National television programmes and communication campaigns were conducted and pilot surveys on AMU and AMR in key culture species as well as training activities on good antibiotic use in aquaculture were carried out.

However, there are still gaps, issues and constraints in the implementation of regulations and plans for AMU and AMR in aquaculture and livestock production in Viet Nam that need long-term efforts by both public and private sectors to overcome. These include:

- Difficulties in collecting accurate data on AMU from farmers or drug stores to assess the status of AMU in specific systems/species; lack of linkage between antibiotics monitoring systems on human and animal health;
- Inadequate specific regulations on the management of antibiotic use and control of AMR in aquaculture; lack of guidelines on AMR surveillance in aquaculture; low level of enforcement in implementing regulations;
- A vast majority of farms are small scale with low investments; antibiotic abuse for disease prevention and control in livestock production and aquaculture as well as in growth promotion is considerable;
- Farmers, drug sellers and local communities have limited knowledge, especially on AMR issues;
- Antibiotics can be purchased without veterinarian prescriptions in contravention of the law; and
- Suboptimal capacity for AMR testing in laboratories.

List of antibiotics permitted for distribution in Viet Nam. The Minister of MARD issued Circular No 10/2016/TT-BNNPTNT dated 1 June 2016 on the list of aquatic veterinary medicines permitted for distribution within Viet Nam (Table 9).

List of banned antibiotics in aquaculture in Viet Nam: Circular No 10/2016/TT-BNNPTNT stipulates the list of chemicals and antibiotics prohibited for use in aquaculture

(Table 10). The DAH shall regularly review the list and submit updates to the Minister of MARD for amendment and update the list based on management requirements and requests from importing countries for aquatic animals and aquatic animal products (for example, in Circular No. 15/2009/TT-BNN dated 17 March 2009 of MARD, the list of banned chemicals and antibiotics regulated included 19 chemicals and antibiotics; however, in Circular No 10/2016/TT-BNNPTNT (replacing Circular No 15/2009/TT-BNN), 24 chemicals and antibiotics were listed).

Table 9. List of antibiotics approved for use in aquaculture in Viet Nam

Antibiotics
Amoxicillin
Doxycycline
Erythromycin
Florfenicol
Oxytetracycline
Sulphadiazine, trimethoprim
Sulphadimethoxine, ormetoprim
Sulphadimethoxine, trimethoprim
Sulphadimidine, trimethoprim
Sulphamethoxazole, trimethoprim

Source: MARD, 2016a.

National Action Plan on AMU and AMR following the One Health initiative

Viet Nam was the first country in WHO's Western Pacific Region to approve the National Action Plan (NAP) on combating antibiotic resistance. Viet Nam also established the national public health network to implement the 'National Action Plan on Drug Resistance 2013-2020', according to Decision No. 2174/QĐ-BYT dated 21 June 2013 wherein the Ministry of Health (MOH) is the lead agency, while MARD is one of the key agencies for implementing the NAP (MoH, 2013).
The main objective of the NAP is to improve people's health care by preventing and controlling drug resistance and raising the quality and effectiveness of medical examination. The NAP has six main activities: (1) raise awareness of community and public health staff about drug resistance; (2) strengthen and improve the capacity of the national surveillance system on AMU and AMR; (3) ensure the supply of essential drugs of high quality; (4) promote safe, prudent and responsible use of drugs; (5) strengthen the control of infection; and (6) strengthen the judicious and responsible use of antibiotics in cropping, livestock production and aquaculture.

To further support the multisectoral approach for the control of AMR, in October 2016, the MoH established the National Steering Committee on Prevention of AMR for the period 2016-2020 (Decision No. 5888/QĐ-BYT dated 10 October 2016). The committee has 31 members from the four ministries and members from external partner institutions.

Table 10. List of chemicals and antibiotics banned for use in aquaculture in Viet Nam (according to Circular No. 15/2009/TT-BNN and Circular No. 10/2016/TT-BNNPTNT)

Names of chemicals and antibiotics	
Circular No. 15/2009/TT-BNN	**Circular No. 10/2016/TT-BNNPTNT**
Aristolochia spp. and their products	*Aristolochia* spp. and their products
Chloramphenicol	Chloramphenicol
Chloroform	Chloroform
Chlorpromazine	Chlorpromazine
Colchicine	Colchicine
Dapsone	Dapsone
Dimetridazole	Dimetridazole
Metronidazole	Metronidazole
Nitrofuran (including furazolidone)	Nitrofuran (including furazolidone)
Ronidazole	Ronidazole
Green malachite	Green malachite
Ipronidazole	Ipronidazole
Other nitroimidazoles	Other nitroimidazoles
Clenbuterol	Clenbuterol
Diethylstilbestrol (DES)	Diethylstilbestrol (DES)
Glycopeptides	Glycopeptides
Trichlorfon (dipterex)	Trichlorfon (dipterex)
Gentian violet (crystal violet)	Gentian violet (crystal violet)
Fluoroquinolones	Fluoroquinolones
-	Trifluralin
-	Cypermethrin
-	Deltamethrin
-	Enrofloxacin
-	Ciprofloxacin

Sources: MARD, 2009; 2016a.

AMR was identified as a key component of the Global Health Security Agenda of Vietnam through which a five-year plan to prevent and control the emergence and spread of AMR via effective and rational use of antibiotics in humans and animals was also established. In 2018, various activities were conducted or are ongoing: (1) annual communication activities/meetings on AMU and AMR ; (2) development of regulations and technical guidelines on clinical pharmacological activity, drug use in treatment, drug description; (3) standardized professional materials/protocols related to diagnostics and treatment with antibiotics; (4) promulgation of the Aide Memoire on 'Multi-stakeholder engagement to combat AMR in Vietnam' (led by the DAH of MARD and the Drug Administration of Vietnam [MoH]) (MoH, MARD, MOIT and MONRE, 2015); (5) increased awareness of AMU and the risks of AMR; (6) MARD promulgation of Decision No. 2625/QĐ-BNN-TY dated 21 June 2017 on the 'National Action Plan for Management of AMU and Control of AMR in Livestock Production and Aquaculture in the Period 2017-2020' (MARD, 2017b).

Strategies and actions for addressing AMR risks in aquaculture

Strategies and actions to mitigate AMR risks in livestock production and aquaculture proposed in the NAP include:

- Strengthening governance for AMU management and AMR control in livestock and aquaculture;
- Improving legislations on AMR and AMU management: (1) identify gaps and irrelevant elements in the national legislation for the management and monitoring of AMU in livestock production and aquaculture; (2) develop regulations to limit and/or ban AMU in prevention of diseases for aquatic animals; and (3) review and amend the regulations related to prescription and sales of prescribed antibiotics including guidance and control of sales of prescription and antibiotics in veterinary activities;
- Monitoring the implementation of regulations: (1) conduct inspections/audits of relevant stakeholders involved in sales or use of antibiotics in livestock and aquaculture, from import to the farm level; and (2) enhance monitoring of antibiotic residues in animal-originated food produced for both export and domestic consumption; monitored results published;
- Increasing awareness of farmers, drug shop owners on AMU and the risks of AMR development via communication campaigns (such as mass media, social media, leaflets and other advocacy tools), training, seminars, AMR awareness week events and so forth;
- Encourage the use of alternatives to antibiotics: (1) promote GAPs to reduce needs for antibiotic treatment at the farm level (e.g. GlobalGAP, VietGAP or other international standards in aquaculture), improve application of biosecurity, vaccination, good hygiene practices through the food supply chain; (2) enhance the usage of diagnostic tools and facilitate the implementation of diagnosis before prescription/use of antibiotics for treatment purposes; and (3) facilitate research activities as well as evaluation of alternative treatment measures to AMU such as probiotic products, herbal extractions, etc.
- Pilot research on the usage of herbal extracts to replace antimicrobials in prevention and treatment of pathogens in aquaculture in Viet Nam. RIA1 is conducting experiments on the herbal product KN0412 to treat haemorrhagic diseases in freshwater fish. VTS1-T is another product extracted from herbs (A. sativum [garlic] and Wedelia chinensis) which can be used to cure white faeces disease in shrimps. Garlic is the most popular and many farmers use it for prevention and control of diseases in shrimp. Test results of herbal garlic extract showed that six major bacterial pathogens in fresh- and brackishwater were susceptible to this product. A mixture of 2 kg garlic + 2 kg salt + 20 g $CuSO_4$ + 20 g $KMnO_4$ diluted with 30 to 50 litres of water and then sprayed on 0.133 ha pond was effective in treating and controlling diseases in shrimps (Bui, 2006).

Conclusion and recommendations

Aquaculture plays an important role in the agriculture sector. It contributes significantly to Viet Nam's economy and generates jobs for many farmers, especially in remote and rural areas. Of the farmed aquaculture species, brackishwater shrimps (P. monodon and L. vannamei) and pangasius catfish are the two major cultured species for export. However, aquaculture in Viet Nam is significantly constrained by disease issues so farmers have to use antimicrobials to control pathogens which results in AMR development. Survey results revealed that antibiotics were used widely for both prevention and control of diseases in aquaculture, especially in small-scale households. Moreover, awareness of farmers on AMU and AMR issues was very limited so antibiotic abuse is an issue that needs to be addressed. It was difficult to estimate the quantity of antimicrobials used in the aquaculture sector due to the lack of a monitoring system to collect data on AMU. Initial survey results for tilapia and freshwater fish showed that important bacterial pathogens are resistant to many types of antibiotics.

Viet Nam has been listed by international organizations as a country with a high level of AMR development. In this context, the government has paid very high attention to developing capacity for better management of AMU and AMR using the One Health initiative. Several key activities have been implemented for the aquaculture component including legislation development, awareness dissemination, training and education, surveys to obtain basic information about AMU and AMR, applying best practices, and close collaboration with international organizations (e.g. WHO, OIE, FAO and NACA) to implement activities on AMU and AMR.

To effectively combat AMR, the Vietnamese Government should continue to implement the following AMU-/AMR-related activities:

- AMR should be merged into the One Health initiative, taking into account the environment that plays a key role in AMR diffusion;
- Increasing the availability and use of rapid and reliable diagnostics and antimicrobial susceptibility tests, including at the farm level;
- Establishing targets for reduction of the use of antimicrobials;
- Increasing responsibility taken by veterinarians/professionals for prescribing antimicrobials;
- Development of appropriate national policies and controls of prudent use of antimicrobials, including the adoption of good health management and hygiene practices (biosecurity) as alternatives to antibiotics;
- Training and education for veterinarians and end-users of antimicrobials on AMR and raising public awareness; and
- Coordination at the global level and improving intersectoral and multidisciplinary collaborations.

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FAO Regional Office for Asia and the Pacific
FAO-RAP@fao.org
http://www.fao.org/asiapacific/en/
Food and Agriculture Organization of the United Nations
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