APEC Guidebook on Early Detection of Diseases Affecting Tilapia and Rainbow Trout

APEC Oceans and Fisheries Working Group

September 2026

Asia-Pacific
Economic Cooperation

APEC Guidebook on Early Detection of Diseases Affecting Tilapia and Rainbow Trout

APEC Ocean and Fisheries Working Group

September 2026

APEC Project: OFWG 204 2024A

Produced by

Vanessa Quevedo Alvarado (National Authority for Health and Safety in Fisheries and Aquaculture, SANIPES, Peru)
Alicia Gallardo Lagno (Consultant)

For
Asia-Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org

APEC#226-OF-03.3

Table of Contents

List of Acronyms

APEC	Asia-Pacific Economic Cooperation
AMR	Antimicrobial Resistance
BKD	Bacterial Kidney Disease
FAO	Food and Agriculture Organization of the United Nations
IPN	Infectious Pancreatic Necrosis
ISKNV	Infectious Spleen and Kidney Necrosis
IHN	Infectious Hematopoietic Necrosis
NACA	Network of Aquaculture Centres in Asia-Pacific
OFWG	Oceans and Fisheries Working Group
SOFIA	State of World Fisheries and Aquaculture
SANIPES	National Authority for Health and Safety in Fisheries and Aquaculture in Peru
SERNAPESCA	National Fisheries and Aquaculture Service in Chile
TiLV	Tilapia Lake Virus
VHS	Viral haemorrhagic septicemia
WAHIS	World Animal Health Information System
WOAH	World Organization for Animal Health

1. Executive Summary

Developed under APEC project OFWG_204_2024A, this Guidebook provides practical guidance to support the early detection, notification and response to priority diseases affecting tilapia and rainbow trout. It is based on a systematic review of scientific literature, as well as international and regional disease reporting systems and domestic notification frameworks across APEC economies. A structured, evidence-based approach was used to analyse diseases by species and subregion, identifying those of the highest impact and relevance for early detection.

For tilapia, the guidebook prioritises streptococcosis, tilapia lake virus (TiLV), edwardsiella infections and infectious spleen and kidney necrosis virus (ISKNV). For rainbow trout, the priority diseases are infectious haematopoietic necrosis (IHN), infectious pancreatic necrosis (IPN), flavobacteriosis and bacterial kidney disease (BKD). These diseases pose the greatest health risks to APEC economies due to their mortality impact, frequency and, in some cases, relevance to the One Health approach and transboundary nature.

The guidebook focuses on the early detection of disease through Level 1 diagnosis. Level 1 diagnosis relies on observations of abnormal behaviour, water parameters changes, mortality, and clinical signs at farm level. This is complemented by a basic environmental assessment and veterinary anamnesis. The guidebook is a practical application for early disease detection called 'Watch, Write and Warn', which aims to support small-scale farmers in the field, particularly regarding bacterial diseases. The app provides recommendations to reduce the incidence and impact of diseases.

The Guidebook reviews disease notification procedures across APEC economies, highlighting common structures, as well as areas of transparency, digitalization and producer engagement that could be improved. Although systems vary, the analysis identifies clear opportunities to strengthen early warning systems by providing practical tools, improving communication and achieving progressive harmonisation in line with international standards.

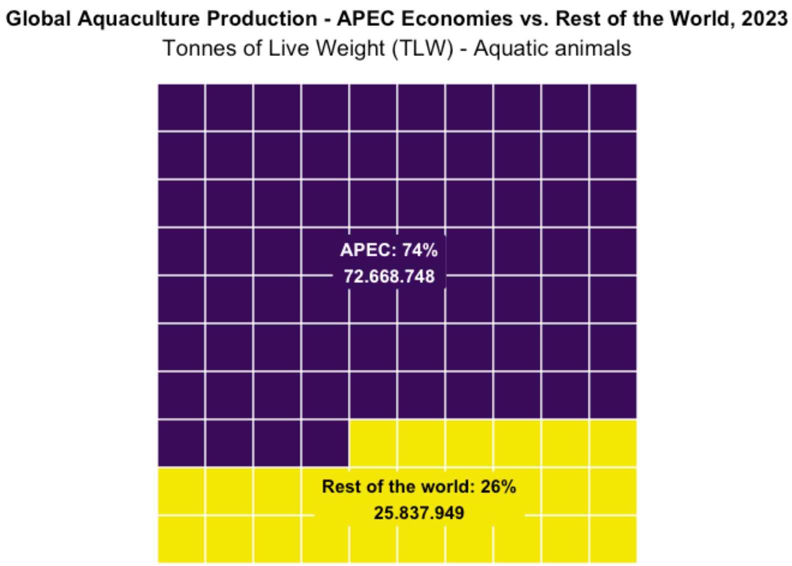
Overall, this guidebook provides APEC economies with a practical reference to help them strengthen their early detection systems for tilapia and rainbow trout, enhance their biosecurity measures and support the development of sustainable aquaculture, resilient food systems and safe trade within the region.

2. Introduction and Background

Aquaculture has become an essential component of global food security, trade, and employment in recent decades. According to SOFIA 2024, global fisheries and aquaculture production reached 185.4 million tonnes live weight equivalent in 2022, of which aquaculture contributed 94.4 million tonnes: for the first time, aquaculture production surpassed capture fisheries in total supply. In the same year, apparent per capita consumption of aquatic products of animal origin was estimated at 20.7 kg, maintaining a long-term upward trend. On the trade front, exports of aquatic products of animal origin reached 70 million tonnes (live weight equivalent) for a value of nearly USD 192 billion, an all-time high (FAO, 2024).

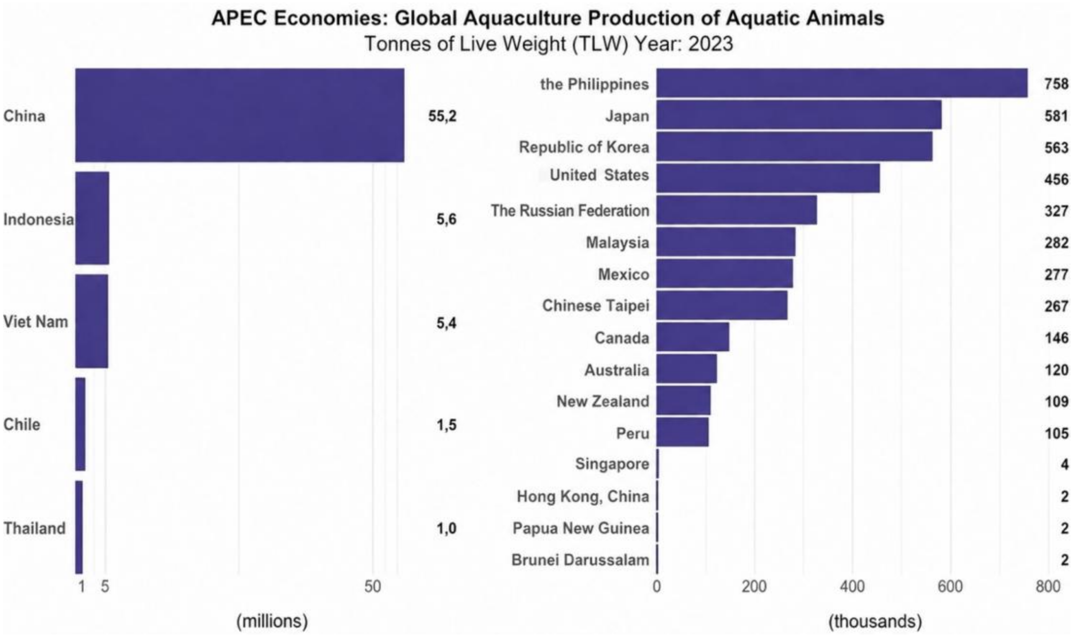
Based on official data compiled by FAO, 2023 and processed for this project, the 21 APEC economies account for approximately 74% of global aquaculture production of aquatic animals in recent years (Figure N°1).

Figure N°1
APEC aquaculture production versus rest of the world

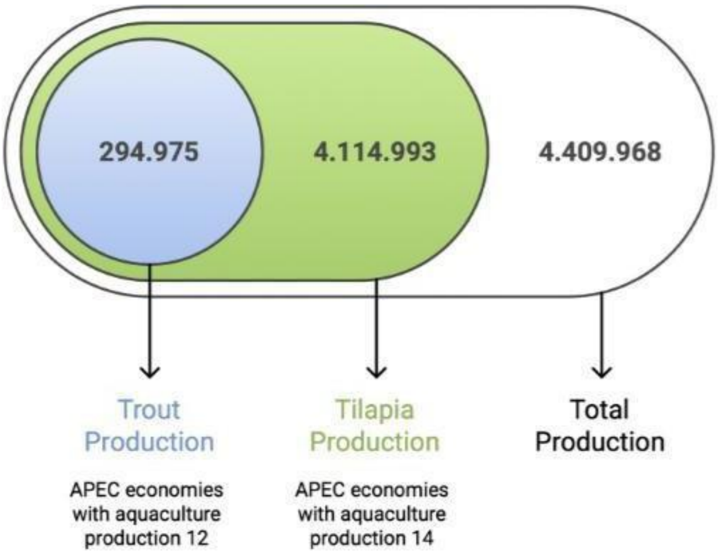


The following shows the aquatic animal production by economy:

Figure N° 2
APEC Economies: Global aquaculture production of aquatic animals

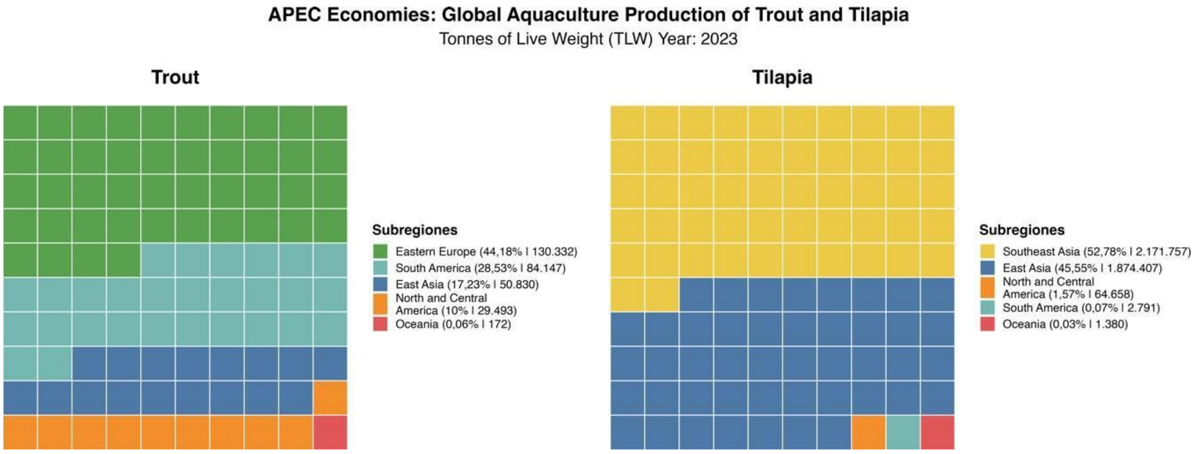


Regarding the distribution of tilapia and trout, the situation is as follows:



The distribution in APEC economies is shown in Figure N°3 below:

Figure N° 3
APEC Economies: Global production of trout and tilapia in aquaculture



Tilapia and rainbow trout are among the most economically and nutritionally significant aquaculture species in APEC economies. Together, they represent a substantial proportion of inland and cold-water aquaculture production. Nile tilapia (*Oreochromis niloticus*) dominates freshwater systems in Asia and Southeast Asia, while rainbow trout (*Oncorhynchus mykiss*) play a strategic role in temperate and high-altitude production systems across the Americas, East Asia, and Oceania. These species support food security, rural livelihoods, domestic markets and international trade, particularly for small- and medium-scale producers.

However, the rapid expansion and intensification of tilapia and trout farming have increased the risk of infectious diseases emerging and spreading, including transboundary viral and bacterial pathogens. These diseases have the capacity to cause high mortality rates, chronic production losses, trade disruptions, and increased antimicrobial use. These impacts disproportionately affect small-scale producers, who often have limited access to diagnostics and veterinary services.

Early disease detection is therefore critical to the sustainable development of aquaculture. Recognizing abnormal mortality patterns and clinical signs in a timely manner enables rapid reporting, confirmatory diagnosis and the implementation of control measures, thereby reducing the scale and duration of outbreaks. Early detection also strengthens domestic and regional surveillance systems, supports compliance with WOAH reporting obligations and improves confidence in the health status of aquatic animals for domestic and international markets.

In the context of APEC, enhancing the capacity for early detection of tilapia and rainbow trout directly contributes to the resilience of food systems, biosecurity and responsible trade, while aligning with the FAO Blue Transformation Roadmap and the WOAH Aquatic Animal Health Strategy.

3. Methodology

A systematic literature review (2000–2025) was conducted to inform the creation of a practical guidebook on the early detection of significant diseases affecting tilapia and rainbow trout in APEC economies.

The period 2015–2025 was emphasized, reflecting the increased emergence and spread of aquatic animal diseases over the last decade. Sources in both English and Spanish were reviewed to ensure broad geographic and institutional coverage.

For the purposes of the analysis, the economies were grouped according to the following table:

TABLE 1: APEC ECONOMIES BY GEOGRAPHICAL SUBREGION

SUBREGION	ECONOMIES
North and Central America	Canada; Mexico; United States.
South America	Chile; Peru.
Southeast Asia	Brunei Darussalam; Indonesia; Malaysia; The Republic of the Philippines; Singapore; Thailand; Viet Nam.
East Asia	People's Republic of China; Hong Kong, China; Japan; Republic of Korea; Chinese Taipei.
Eastern Europe	The Russian Federation
Oceania	Australia; New Zealand; Papua New Guinea.

Information was collected from official international and regional reporting systems, including WAHIS, NACA Quarterly Aquatic Animal Disease (QAAD) reports, the FAO databases, the websites of domestic competent authorities, legal instruments, technical guidelines and peer-reviewed scientific literature.

The methodological approach comprised four components:

(I) Identification of the main diseases affecting tilapia and rainbow trout in APEC subregions.

(II) Compilation of technical information for standardized disease data sheets.

(III) Collection of representative images of behaviour, significant lesions to facilitate visual identification and training.

(IV) Documentation of economy-wide disease notification procedures and early warning systems.

Based on literature review and criteria, diseases affecting tilapia and rainbow trout in APEC economies were selected to support early detection guidance.

4. Main Diseases Affecting Tilapia and Rainbow Trout in APEC Economies

4.1 Tilapia

The main infectious diseases (both viral and bacterial) affecting tilapia in APEC economies are shown below, because of the analysis.

TABLE 2: APEC TILAPIA VIRAL DISEASES

DISEASE	CAUSATIVE AGENT	KEY REMARKS	REFERENCES
Tilapia Lake Virus disease (TiLV)	Tilapia lake virus (TiLV)	Emerging disease; high mortalities; trade relevance; WOAH-listed	WOAH, 2023; SANIPES, 2023a;Taukhid et al., 2024; Abdullah et al., 2018; Dong et al.,2017; Tran et al., 2022.
Infectious splenic and renal necrosis virus (ISKNV), now listed as infection by *Megalocytivirus pagrus 1*	*Megalocytivirus pagrus 1* (ISKNV)	Emerging disease; mass mortalities; trade relevance; WOAH- listed	WOAH, 2023; Al-Hussinee et al., 2019; Saksmerprome et al., 2025; Suebsing et al., 2016.
Tilapia parvovirus (TiPV)	Tilapia parvovirus	Emerging disease reported mainly in Asia	Yamkasem et al., 2021; Das & Dong, 2024; Hatkaewchai et al., 2025.

TABLE 3: APEC TILAPIA BACTERIAL DISEASES

DISEASE	CAUSATIVE AGENT	KEY REMARKS	REFERENCES
Streptococcosis	*Streptococcus agalactiae; Streptococcus iniae*	Major cause of economic losses; outbreaks linked to high temperatures; zoonotic potential	Hernández-Hernández et al., 2023; Haenen et al., 2023;SANIPES, 2023b; Taukhid et al., 2023;Anshary et al., 2014; Syuhada et al., 2020; Barkhamet al., 2019; Koh et al., 2004; Chitmanatet al., 2016; Tahiluddin et al., 2021; Zhang et al 2022; Zhang et al., 2024; Sapugahawatte et al., 2022; Li et al., 2025; Sudpraseart, et al., 2021.
Edwardsiellosis	*Edwardsiella tarda; Edwardsiella ictaluri*	Systemic septicemia; frequent co-infections	Soto et al., 2012; Mohanty & Sahoo, 2020; Sierralta et al., 2020; Chitmanatet al., 2016; Nhinh et al.,2022; Trung et al., 2024; Oh et al., 2020; Nhinh et al.,2022;
Aeromoniasis	*Aeromonas hydrophila; Aeromonas veronii*	Opportunistic disease associated with stress and poor water quality	Haenen et al., 2023; Castañeda et al., 2025; Quek et al., 2020; Ridzuan et al., 2022; Chitmanatet al., 2016; Tahiluddin et al.,2021; Nhinh et al.,2022; Lam, 2023; Ivanov & Sidorova, 2022
Francisellosis	*Francisella noatunensis subsp. orientalis*	Chronic disease in intensive farming systems	Ortega et al., 2016;Ming Xu et al., 2024; Tsai et al., 2017.
Flavobacteriosis	*Flavobacterium columnare; Flavobacterium oreochromis; Flavobacteriumdavisii*	Skin and gill lesions; common in warm-water systems	LaFrentz et al., 2022; Chitmanatet al., 2016; Ridzuan et al., 2022; Ahmed et al., 2025)
Pseudomonas infections	*Pseudomonas fluorescens Pseudomonas putida Pseudomonas aeruginosa*	Opportunistic bacterial septicemia under stressful farming conditions Coinfections (e.g. Streptococcosis, Aeromoniasis)	Chitmanatet al., 2016 ; Tahiluddin et al., 2021.

4.2 Rainbow Trout

The main infectious diseases (both viral and bacterial) affecting rainbow trout in APEC economies are shown below, as a result of the analysis.

TABLE 4: RAINBOW TROUT VIRAL DISEASES

DISEASE	CAUSATIVE AGENT	KEY REMARKS	REFERENCES
Infectious haematopoietic necrosis (IHN)	Infectious haematopoietic necrosis virus (IHNV)	WOAH-listed disease; high mortality in juveniles	Kim et al., 2023; Li et al., 2024.
Infectious pancreatic necrosis (IPN)	Infectious pancreatic necrosis virus (IPNV)	Acute disease and chronic carriers; wide distribution	Dopazo, 2020; Salgado-Miranda et al,, 2020Fisheries and Oceans Canada, 2017; SANIPES, 2024; Duan et al., 2021;
Viral haemorrhagic septicaemia (VHS)	Viral haemorrhagic septicaemia virus (VHSV)	WOAH-listed disease; regional genotypes	Thompson et al., 2011; Garver and Hawley, 2021

TABLE 5: RAINBOW TROUT BACTERIAL DISEASES

DISEASE	CAUSATIVE AGENT	KEY REMARKS	REFERENCES
Bacterial kidney disease (BKD)	*Renibacterium salmoninarum*	Chronic disease; vertical transmission	Boerlage et al., 2017; Honeyfield et al., 2015; SERNAPESCA, 2024; Kong K et al., 2024; Alontseva et al., 2021
Flavobacteriosis / Cold-water disease	*Flavobacterium psychrophilum*	High mortality in fry; cold-water systems	Cipriano & Holt, 2005; Deng et al., 2024; Alcántara-Jauregui et al.,2022; Seafood Watch, 2023; León et al. 2009; Távara et al., 2019 Apayco et al.,2020; Deng et al., 2024; Park et al, 2021; Nikiforov-Nikishin et al., 2017

Enteric redmouth disease (Yersiniosis)	*Yersinia ruckeri*	Systemic disease; globally distributed	Silva & Austin, 2017; Carson et al., 2019; Wade, J., 2019; Alcántara-Jauregui et al.,2022; Silva & Austin, 2017; Rosadio et al., 2018; Mesías et al., 2019; Droshnev et al., 2019; Carson et al., 2019
Typical and atypical furunculosis.	*Aeromonas salmonicida subsp. salmonicida* (typical) other subspecies or strains of *A. salmonicida* (atypical)	Acute outbreaks; muscle abscesses (typical) Atypical: Subacute or chronic conditions; less defined skin lesions. There are not always classic abscesses.	Boily et al., 2019; Toro Montenegro, 2020; Liu et al., 2025; Ivanov & Sidorova, 2022; SERNAPESCA), 2024
Emerging bacterial infections	*Weissella spp.,* *Pseudomonas spp.,* *Edwardsiella spp.* *Acinetobacterjohnsonii* *Weissella ceti* *Edwarsiella* *Lactococcus garviae* *Vagococcus salmoninarum*	Emerging/regional relevance	Droshnev et al., 2019; Oh et al., 2019; Wang et al., 2019; Yaun et al., 2023; Medina et al.,2020; Reichley et al., 2017; Alcántara-Jauregui et al.,2022; Yardimci et al., 2016.

4.3 Selection of Priority Diseases for Early Detection

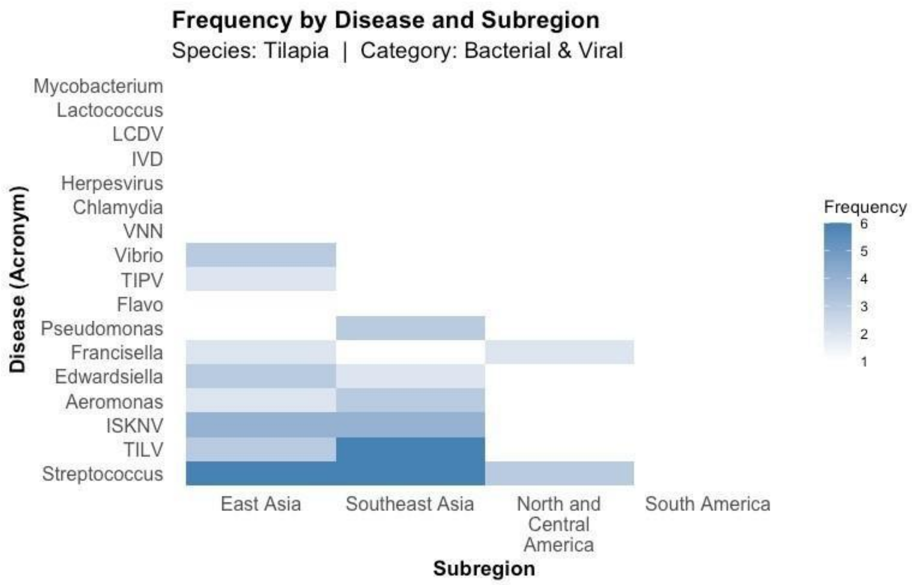
4.3.1 Disease Selection Criteria

The criteria used to select the diseases in the guidebook considered mortality rates; frequent farm-level losses; trade impacts and potential implications for zoonoses and AMR.

4.3.2 Tilapia

The diseases frequency by disease affecting tilapia in APEC economies are shown in the following heat map:

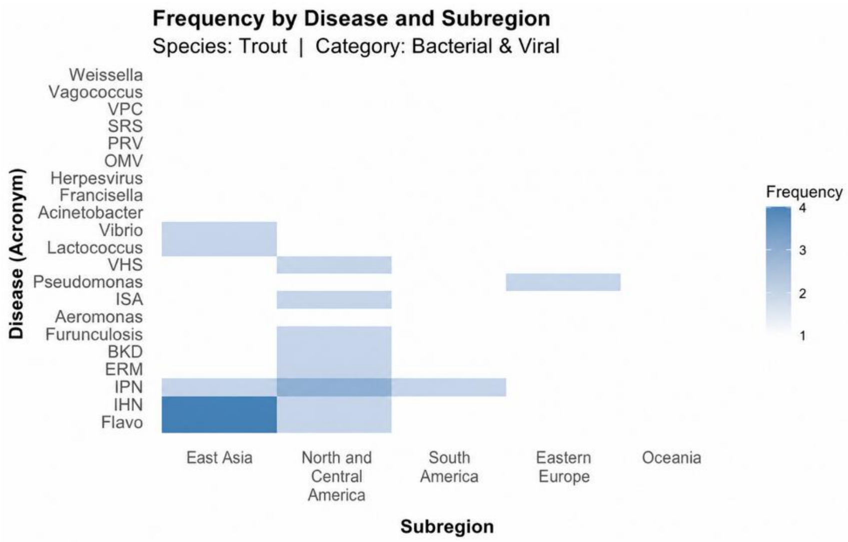
Figure N°4
Tilapia: APEC frequency by disease and subregion
Own elaboration



4.3.3 Rainbow Trout

The frequency of disease affecting rainbow trout in APEC economies is shown in the following heat map:

Figure N° 5
Rainbow Trout APEC frequency by disease and subregion
Own elaboration



The prioritized diseases for the APEC guidebook on early detection, as described in 4.3.1, are as follows:

TABLE 6: PRIORITY DISEASES SELECTED FOR INCLUSION IN THE APEC EARLY DETECTION GUIDEBOOK

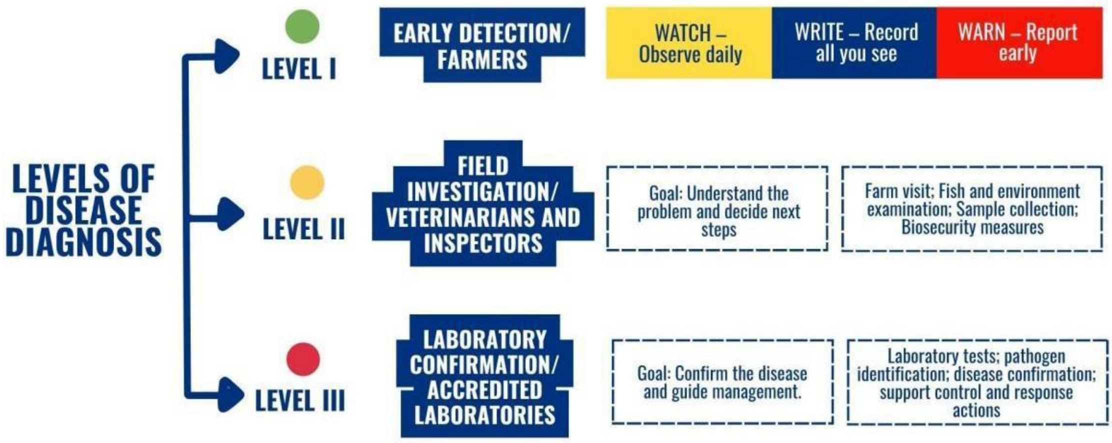
TILAPIA	RAINBOW TROUT
Viral diseases 1. Tilapia lake virus (TiLV). 2. Infectious spleen and kidney necrosis virus (ISKNV).	**Viral diseases** 1. Infectious hematopoietic necrosis (IHN) 2. Infectious pancreatic necrosis (IPN)
Bacterial diseases 1. Streptococcosis (principally *Streptococcus agalactiae* and *S. iniae*), 2. *Edwardsiella spp.* (*E. tarda/E. ictaluri*).	**Bacterial diseases** 1. Flavobacteriosis 2. Renibacteriosis (BKD)

5. Early Disease Detection in Aquaculture: A Guidebook for Fish Farmers

Early disease detection is one of the most effective tools to protect fish health, farm productivity, and livelihoods. In aquaculture, diseases rarely appear suddenly, they usually start with small changes in fish behaviour, appearance, or water quality.

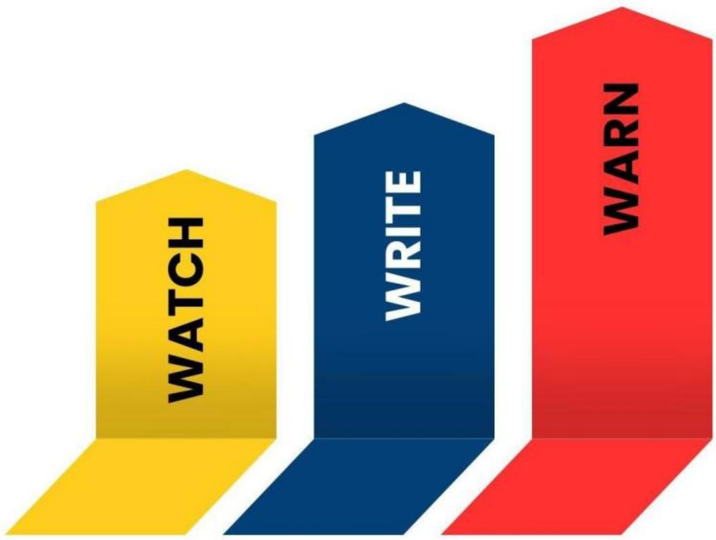
To help farmers, technicians, and authorities respond in a timely and organized way, aquatic animal health diagnosis is commonly described using three progressive levels: Level I, Level II, and Level III. These levels move from simple observation on the farm to advanced laboratory confirmation, depending on the severity and complexity of the problem.

Figure N° 6
Levels of disease diagnosis

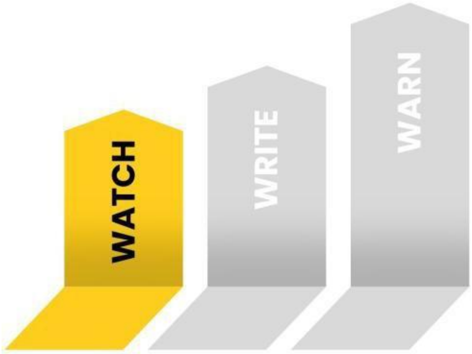


5.1 Early Disease Detection at Farm Level

Watch, **Write & Warn** (**W, W & W)** is a simple and practical approach designed to help fish farmers recognize health problems early and take timely action to reduce losses and prevent disease spread.



WHAT DO YOU WATCH FOR?



MORTALITY PATTERNS

→ Sudden mortality
→ Increasing daily mortalities
→ Most of the fish deaths are concentrated in one pond or cage

WATER QUALITY

→ Low oxygen.
→ Sudden temperature changes.
→ Dirty, green or foamy water.
→ Recent rainwater exchange or management.

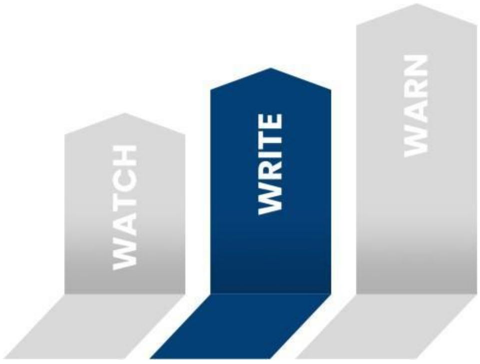
EXTERNAL APPEARANCE: "WHAT DO YOU SEE ON THE FISH BODY"

→ Colour changes.
→ Skin ulcers or wounds.
→ Frayed or damaged fins.
→ Red spots or bleeding.
→ Bulging or clouding eyes.
→ Excess mucus on skin.
→ Internal lesions if possible.

BEHAVIOUR: "HOW FISH ACT"

→ Stops eating or eats less than normal.
→ Look tired, move slowly, and do not react normally (lethargy).
→ Slow swimming, weak or isolated fish.
→ Abnormal swimming (spinning, rolling, swimming sideways).
→ Fish gasping at the surface.
→ Fish staying at the bottom or near water inlets.

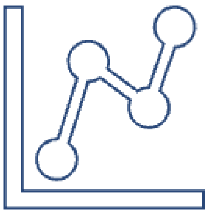
WHAT TO RECORD EVERY DAY?



IMAGES OR VIDEOS OF STEP 1 "WATCH"

→ Behaviour
→ External lesions
→ Internal lesions
→ Water colour and appearance

PRODUCTION PARAMETERS



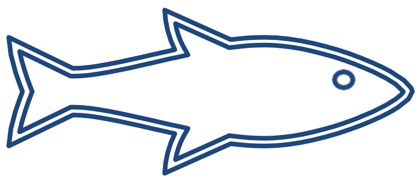
→ Colour changes.
→ Date of event; life stage and identification pond or cage
→ Feeding: normal or less
→ Growth: Bigger or no
→ Deaths: ¿How many?
→ Any work done

WATER AND ENVIRONMENT

→ Water temperature
→ Oxygen (if you can measure it)
→ Weather
→ Water: clear or dirty
→ Algae blooms
→ pH (if available).

FISH MOVEMENTS

→ Where the fish came from?
→ How many fish?
→ Date and time



REPORT EARLY

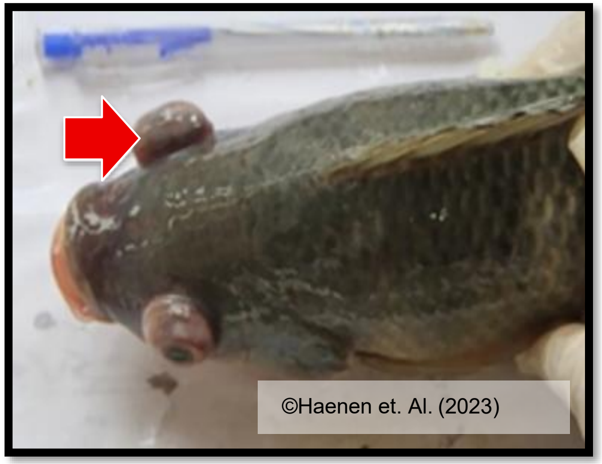
What is reported?

- Information about the suspicion
- Key information about step 1 and 2
- Photographs or videos, if possible

5.2 Practical Application Watch, Write and Warn in Priority Diseases for an Early Warning System.

5.2.1 Tilapia

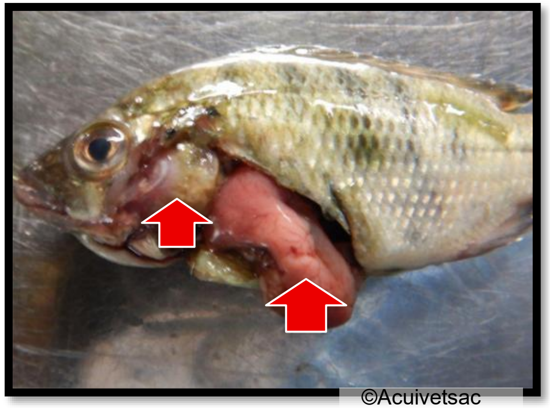
STEP		TILAPIA LAKE VIRUS INFECTION (TiLV)	INFECTIOUS SPLEEN AND KIDNEY NECROSIS (ISKNV)	ESTREPTOCOCCOSIS	EDWARSIELLOSIS
WATCH	BEHAVIOUR	Lethargy or reduced swimming activity • Reducing feeding or loss of appetite • Isolation from the group • General weakness • Reduced response to external stimuli (e.g., feed or disturbance)			
		• Respiratory distress (breathing at surface).	• Abnormal swimming. • Obvious opercular movement (indicating respiratory distress/increased respiratory effort. • Presence of cannibalism (infection is more likely).	• Spiral swimming, loss of balance and disorientation • Surface gasping. • Rapid or labored breathing	• Erratic swimming. • Fish remaining near surface or bottom.

	MORTALITY PATTERNS	• Sudden unexpected increase in mortalities (greater than 2% per day) over several days during the summer months. • Cumulative mortality up to 90% or more within 1 month of stocking fingerlings into freshwater or brackish water ponds. • High mortalities in 1 to 50 g., lower mortalities (approximately 10%) in medium or large fish.	• Low to high mortality (up to 100%) and can depend on water temperature, with higher mortalities occurring at higher water temperatures. • Mortalities 2 to 4 weeks after exposure in areas where the disease is confirmed. • Juveniles are more susceptible to disease than adults.	• Unusual or rising mortalities. • Deaths scattered through cages/ponds (not just one area)	• It can affect fish at all life stages, with a higher susceptibility in juveniles.
	EXTERNAL AND INTERNAL SIGNS	 **Hemorrhage in the pectoral fin**	 **Exophthalmia with bilateral ocular hemorrhage**		

Focal cephalic skin erosion

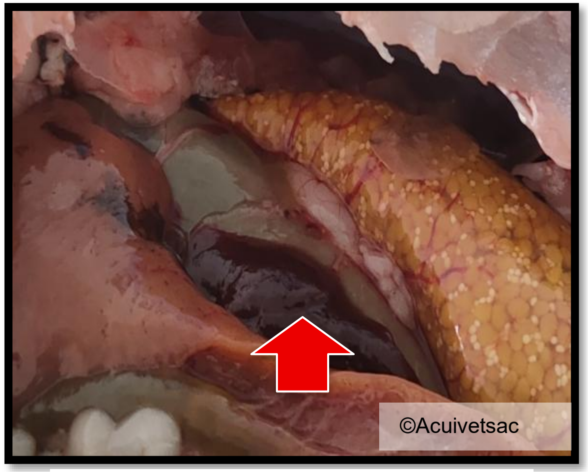
Caudal fin erosion

Hemorrhage in the pectoral

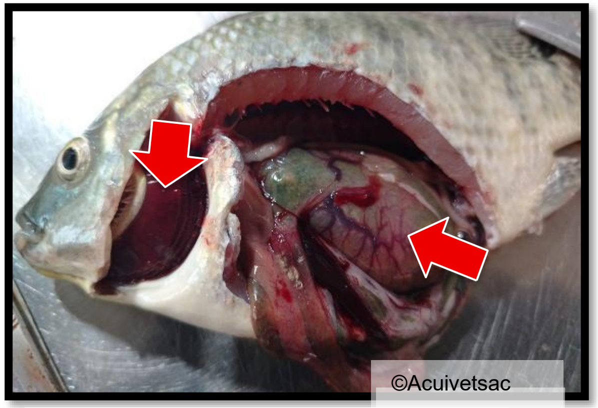


Hepatomegaly with branchial hemorrhage and scale loss

Bilateral submandibular and sublingual hemorrhage

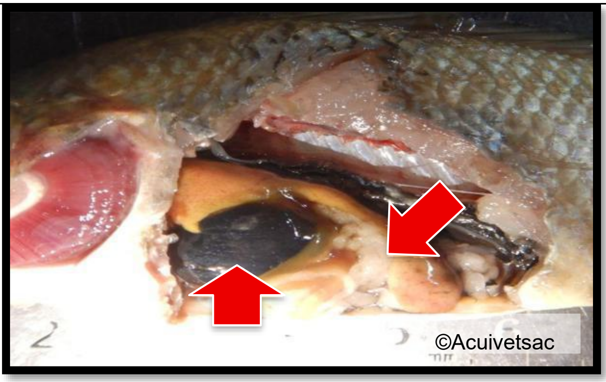


Splenomegaly

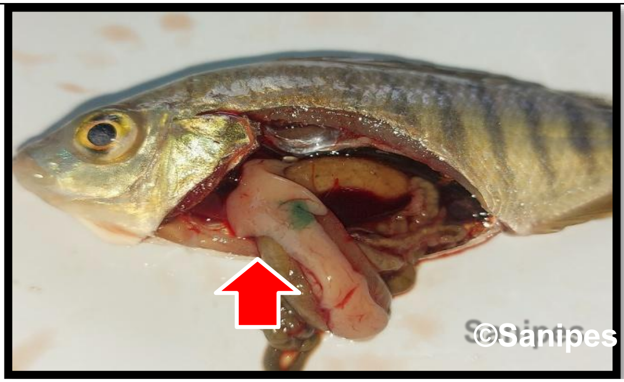


Gastric congestion with perioral haemorrage

Perioral pustule



Yellow liver with biliary dilation



Haemorrhagic ascites / intra-abdominal haemorrhage associated with systemic septicaemia

Congestive and haemorrhagic branchitis with focal lamellar

Meningoencephalitis with cerebral congestion and haemorrhage

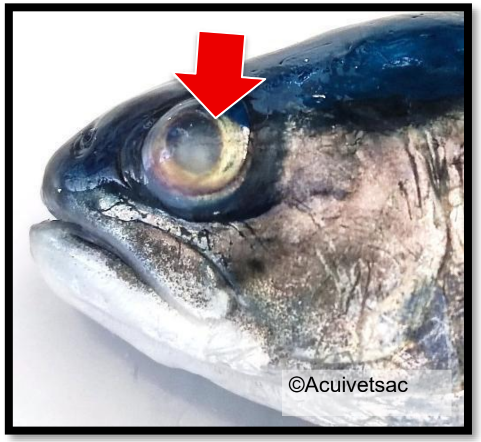
	WATER QUALITY PARAMETERS (thresholds)	• Temperature < 28°C • pH <7.0 o >9.0 • Ammonia > 0.1 mg/L • Nitrite > 0.05 mg/L • Sudden temperature changes • Dissolved Oxygen (DO) ≤ 2 mg/L	• Temperature 25 – 32°C • Dissolved Oxygen (DO) ≤ 2 mg/L • Unionized ammonia (NH_3) 0.15 - 0.2 mg/L	• Temperature ≥ 28°C • Dissolved Oxygen (DO) ≤ 3.5 mg/L • Unionized ammonia (NH_3) 0.42 ≥ mg/L • Sudden temperature changes	• Temperature higher 25°C. • Dissolved Oxygen (DO) ≤ 2.6 mg/L. • Unionized ammonia, NH_3 ≥ 0.29 mg/L • Nitrite ≥ 2.01 mg/L • Salinity 10-20 ppt • High organic matter, uneaten feed, sludge accumulation
WRITE		• Production parameters • Mortality rates. • Life stage affected. • Management practices. • Water parameters (temperature, ammonia and others). • Fish movements.			
WARN		• Disease suspicions must be reported to Aquatic animal health authorities, Veterinarian, extension officer or laboratory according to domestic regulation. • TiLV and ISKNV are WOAH listed diseases.			

Tilapia disease Factsheets are available in **Annex 3.**

5.2.2 Rainbow Trout

STEP		INFECTIOUS HEMATOPOIETIC NECROSIS (IHN)	INFECTIOUS PANCREATIC NECROSIS (IPN)	FLAVOBACTERIOSIS	RENIBACTERIOSIS (BKD)
WATCH	BEHAVIOUR	• Lethargy or reduced swimming activity • Reducing feeding or loss of appetite • Isolation from the group • General weakness			
		• Lethargic swimming with intermittent bouts of frenzied, abnormal activity. • Fish can display spiral swimming, flashing, and have trailing faecal casts.	• Erratic spiral swimming • Pseudo feces	• Fish congregating near inflows (seeking oxygen) • Increased surface activity when gills are affected.	• Loss of balance and irregular swimming
	MORTALIT Y PATTERNS	• Mass mortality of up to 90 % can occur in hatcheries, typically with 100% of the population infected	• Fry and juveniles in freshwater and in smolts recently transferred to seawater, although outbreaks have also been	• It primarily affects fry and juveniles, especially in cold water, and can cause significant	• Chronic pattern: prolonged low mortality

		• Increased mortality in fry or fingerlings and in adults during or just following spawning. • Mortality can occur between 8 and 10°C, but increases significantly above 12°C.	reported in post-smolts and adult fish. • The disease can cause significant death rates in fry and fingerlings from 1 to 4 months of age. Mortality rates are high, reaching 100% in the fry stage.	mortality if not detected early. • Flavobacteriosis caused by *F. psychrophilum* mortality ranges are between 50-60% in all production stages at temperatures of 8 to 14°C	• Broodstock history (vertical transmission risk) • Mortality ranging from 40 to 80 % in all phases of cultivation • Stressors: handling, high density, poor water quality

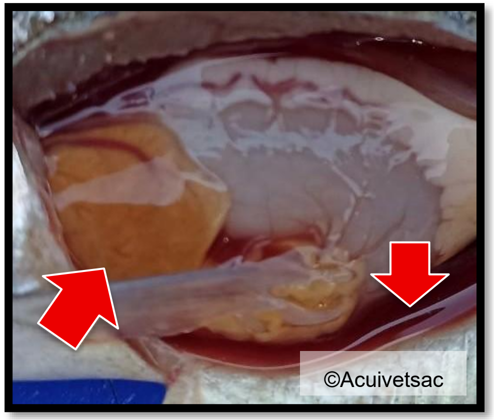
	EXTERNA L AND INTERNA L SIGNS	 **Branchial pallor**  **Corneal opacity**

Ocular hemorrhage

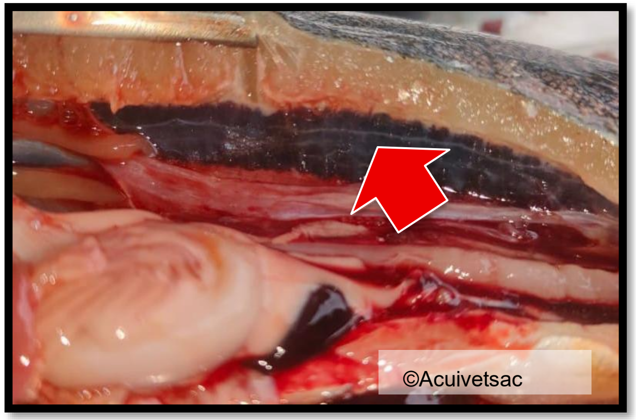
Exophthalmia

Anal hemorrhage

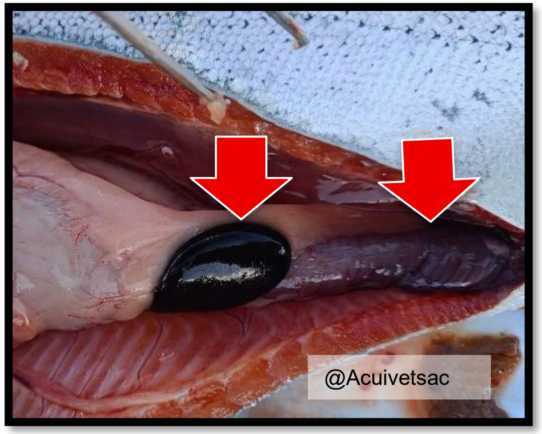
Yellow fecal discharge



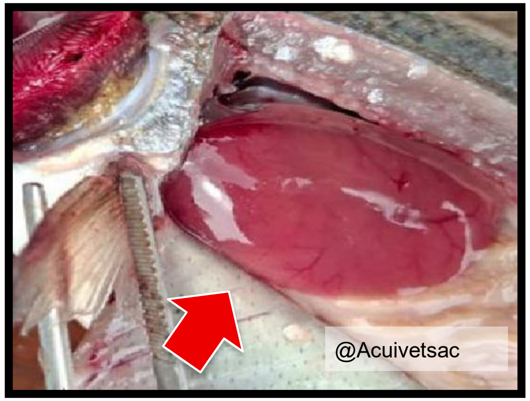
Hepatic icterus with ascites



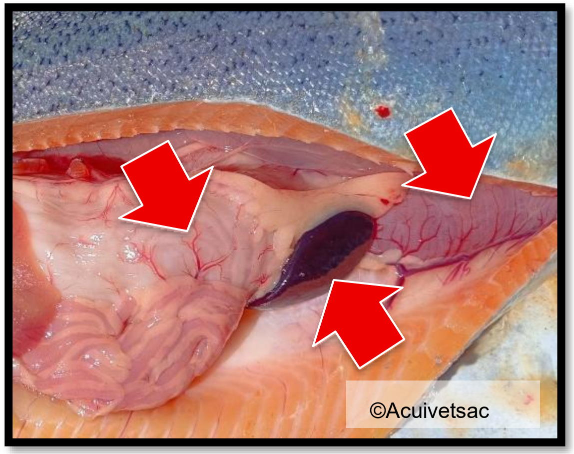
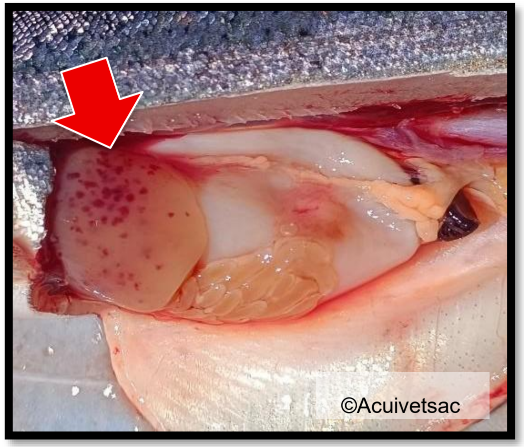
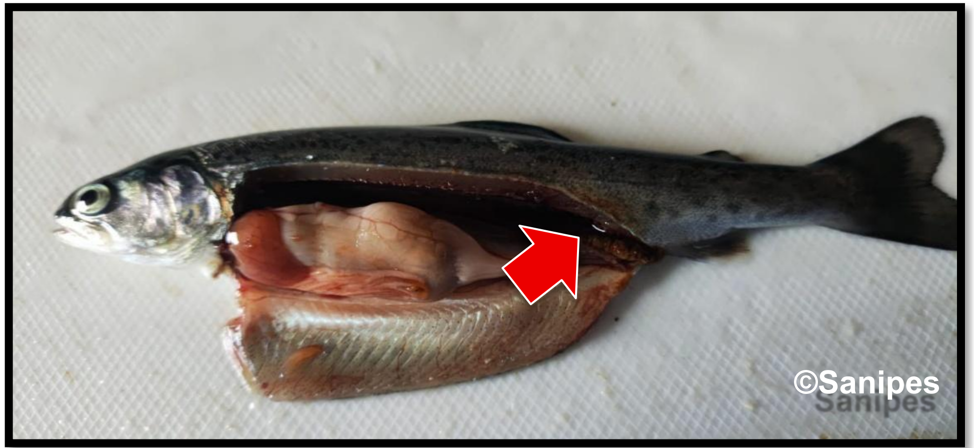
Renal enlargement with irregular margins and congestive



Splenomegaly with intestinal congestion



Hepatic congestion

		 Gastric and intestinal congestion with splenomegaly  Petechial hepatic  Abdominal swelling with fluid accumulation (ascites)

Visible tear in the gill tissue with localized bleeding

Red bruise under the mouth

Unusual dark color in juveniles

Fish with swollen belly

	WATER QUALITY PARAMETERS (thresholds)	• Dissolved Oxygen, DO ≤ 6 mg/L • Temperature 8-12 °C	• Dissolved Oxygen (DO) ≤6 mg/L • Temperature 8 -15 °C.	*F. psychrophilum* • Temperature 8–16 °C • pH 6.5 *F. columnare* • Dissolved Oxygen (DO) ≤ 5 mg/L • Temperature 15–20°C • Nitrites ≥ 0.1 mg/L • Salinity 0.0-0.5%	• Dissolved Oxygen (DO) ≤6 mg/L • Temperature 8-12°C • Dureza <100 mg/L
WRITE		•Production parameters • Mortality rates. • Life stage affected. • Management practices. • Water parameters (temperature, ammonia and others). • Fish movements.			
WARN		•Disease suspicions must be reported to Aquatic animal health authorities, Veterinarian, extension officer or laboratory according to domestic regulation. • IHN is a WOAH listed disease			

Rainbow trout disease Factsheets are available in **Annex 4.**

6. Conclusions

1. A limited number of diseases pose the greatest sanitary risk to tilapia and rainbow trout aquaculture systems in APEC economies.
2. For Tilapia, the dominant threats are Tilapia Lake virus (TiLV), infectious spleen and kidney necrosis virus (ISKNV), streptococcosis and Edwardsiella infections due to high mortality rates, frequent outbreaks and transboundary relevance.
3. The most significant diseases for rainbow trout are infectious haematopoietic necrosis (IHN), infectious pancreatic necrosis (IPN), flavobacteriosis, and bacterial kidney disease (BKD), particularly affecting juvenile stages.
4. There is significant variability among APEC economies in terms of digitalization, diagnostic capacity, and feedback mechanisms within disease notification systems.
5. Standardized disease fact sheets and visual guidance tools effectively support early warning and improve the timeliness of disease reporting.

7. Recommendations for Future APEC Projects

Based on the identified findings, the following strategic recommendations are proposed to guide future APEC initiatives:

1. Develop minimum APEC guidance on the notification of aquatic animal diseases. Establish non-binding regional guidance that defines the minimum elements required for disease notification systems, including timelines, roles and reporting channels.
2. Support the alignment of production profiles with disease surveillance priorities.
3. Encourage economies to periodically review and update their lists of notifiable diseases based on key farmed species, such as trout and tilapia.
4. Improve the transparency and accessibility of disease notification information.

5. Encourage the development of centralized, publicly accessible online platforms that describe disease notification procedures in clear, practical terms.
6. Strengthen farmer engagement in early disease detection.
7. Support training, awareness campaigns and digital tools that enable producers to recognize, and report suspected diseases at an early stage.
8. Consider developing training material in the native language of aquaculture communities.
9. Use digital solutions to enable early detection and reporting. Pilot projects on electronic notification systems, mobile applications and interoperable databases suitable for different levels of capacity should be encouraged. It is recommended to implement a pilot in a given area and time required to validate the designed systems.

8. References

Abdallah, E. S. H., Metwally, W. G. M., Bayoumi, S. A. L. H., Abdel Rahman, M. A. M., & Mahmoud, M. M. (2024). Isolation and characterization of *Streptococcus agalactiae* inducing mass mortalities in cultured Nile tilapia (*Oreochromis niloticus*) with trials for disease control using zinc oxide nanoparticles and ethanolic leaf extracts of some medicinal plants. BMC Veterinary Research, 20, 468. https://doi.org/10.1186/s12917-024-04298-z

Abdullah, A., Ramly, R., Mohammad Ridzwan, M. S., *et al*. (2018). First detection of tilapia lake virus (TiLV) in wild river barb (*Barbonymus schwanenfeldii*) at Timah Tasoh Lake, Malaysia. Journal of Fish Diseases, 00, 1–4. https://doi.org/10.1111/jfd.12843

Aich, N., Paul, A., Choudhury, T.G. and Saha, H. (2022) Tilapia Lake virus (TiLV) disease: current status of understanding. Aquaculture and Fisheries 7(1), 7–17. https://doi.org/10.1016/j.aaf.2021.04.007

Al-Hussinee, L., Subramaniam, K., Surachetpong, W., Popov, V., Hartman, K., Starzel, K., Yanong, R., Watson, C., Ferguson, H., Frasca, S., Jr., & Waltzek, T. (2019). Tilapia lake virus (TiLV): A globally emerging threat to tilapia aquaculture (FA213) [Extension fact sheet]. University of Florida Institute of Food and Agricultural Sciences (IFAS) Extension. https://edis.ifas.ufl.edu/fa213

Alcántara-Jauregui, F. M., Valladares-Carranza, B., & Ortega, C. (2022). Enfermedades bacterianas y sus agentes etiológicos identificados en peces de México: Una revisión. Revista MVZ Córdoba, 27(2), e2387. https://doi.org/10.21897/rmvz.2387

Anshary, H., Kurniawan, R. A., Sriwulan, S., Ramli, R., & Baxa, D. V. (2014). Isolation and molecular identification of *Streptococcus iniae* and *Streptococcus agalactiae* in cultured Nile tilapia (*Oreochromis niloticus*) from Lake Sentani, Papua, Indonesia. SpringerPlus, 3(1), 627. https://doi.org/10.1186/2193-1801-3-627

Apayco N, Huamán R, Sandoval N. 2020. Identificación *de Flavobacterium psychrophilum* en alevines de "trucha arcoíris" (*Oncorhynchus* mykiss), distrito de Huanta, Ayacucho 2019. Investigación 28: 166-171. https://revistas.unsch.edu.pe/index.php/investigacion/article/view/369

Arsan, E. L., Atkinson, S. D., Hallett, S. L., Meyers, T., & Bartholomew, J. L. (2007). Expanded geographical distribution of *Myxobolus cerebralis*: First detections from Alaska. Journal of Fish Diseases, 30(8), 483–491. https://doi.org/10.1111/j.1365- 2761.2007.00834.x

Asia-Pacific Economic Cooperation (APEC). (2022). APEC roadmap on small-scale fisheries and aquaculture 2022–2027. https://www.apec.org/docs/default-source/groups/ofwg/apec-roadmap-on-small-scale-fisheries-and-aquaculture.pdf

Asia-Pacific Economic Cooperation (APEC). (2023). Results of the survey for the status of aquaculture in APEC economies. https://www.apec.org/publications/2023/05/results-of-the-survey-for-the-status- of-aquaculture-in-apec-economies

Attia, R. M., El-Son, M. A., Shafik, S., & Abdelkhalek, N. K.(2025). Pathophysiological and Molecular Characterization of *Streptococcus agalactiae* in Farmed Nile Tilapia. Egyptian Journal of Veterinary Sciences, 1-17. https://doi.org/10.21608/ejvs.2025.395469.2912

Austin, B., & Austin, D. A. (2012). Bacterial fish pathogens: Disease of farmed and wild fish (5th ed.). Springer.

Azad, I. S., Al-Yaqout, A., El-Dakour, S., Kawahara, S., & Al-Roumi, M. (2024). First record of iridovirus (ISKNV) infections in Fourfinger threadfin from Kuwait. Journal of King Saud University-science, 36(9), 103393. https://doi.org/10.1016/j.jksus.2024.103393

Barkham, T., Zadoks, R. N., Azmai, M. N. A., Baker, S., Bich, V. T. N., Chalker, V. J., Chen, S. L., Edwards, G. F., El-Sayed, A., Forde, B. M., *et al*. (2019). One hypervirulent clone, sequence type 283, accounts for a large proportion of invasive *Streptococcus agalactiae* infections in humans and diseased fish in Southeast Asia. Emerging Microbes & Infections, 8(1), 1339–1354. https://doi.org/10.1371/journal.pntd.0007421

Barnes, M. E., & Brown, M. L. (2011). A Review of *Flavobacterium psychrophilum* Biology, Clinical Signs, and Bacterial Cold Water Disease Prevention and Treatment. The Open Fish Science Journal, 4(1), 40–48. https://doi.org/10.2174/1874401X01104010040

Barry, D. E., Veillard, M., James, C. T., Brummelhuis, L., Pila, E. A., Turnbull, A., Oddy-van Oploo, A., Han, X. N., & Hanington, P. C. (2021). qPCR-based environmental monitoring of *Myxobolus cerebralis* and phylogenetic analysis of its tubificid hosts in Alberta, Canada. Diseases of Aquatic Organisms, 145, 119–137. https://doi.org/10.3354/dao03608

Bergmann, S. M., Fichtner, D., Skall, H. F., Schlotfeldt, H. J., & Olesen, N. J. (2003). Age- and weight-dependent susceptibility of rainbow trout *Oncorhynchus mykiss* to isolates of infectious haematopoietic necrosis virus (IHNV) of varying virulence. Diseases of AquaticOrganisms, 55(3), 205-210. https://doi.org/10.3354/dao055205

Bi, B., Yuan, Y., Jia, D., Jiang, W., Yan, H., Yuan, G., & Gao, Y. (2023). Identification and pathogenicity of the emerging fish pathogen *Acinetobacter johnsonii* from a disease outbreak in rainbow trout (*Oncorhynchus mykiss*). Aquaculture Research, 54(?), 1–13. https://doi.org/10.1155/2023/1995494

Boerlage, A. S., Stryhn, H., Sánchez, J., & Hammell, K. L. (2017). Case definition for clinical and subclinical bacterial kidney disease (BKD) in Atlantic salmon (*Salmo salar*) in New Brunswick, Canada. Journal of Fish Diseases, 40(3), 395–409. https://doi.org/10.1111/jfd.12521

Boily, F., Malcolm, G., & Johnson, S. C. (2019). Characterization of *Aeromonas salmonicida* and furunculosis to inform pathogen transfer risk assessments in British Columbia (DFO Canadian Science Advisory Secretariat Research Document 2019/016). Fisheries and Oceans Canada. https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2019/2019_016-eng.html

Brown, L. L., Cox, W. T., & Levine, R. P. (1997). Evidence that the causal agent of bacterial cold-water disease *Flavobacterium psychrophilum* is transmitted within salmonid eggs. Diseases of Aquatic Organisms, 29(3), 213–218. https://doi.org/10.3354/dao029213

C. *et al*. (2021). Phenotype, genotype and pathogenicity of *Streptococcus agalactiae* isolated from cultured tilapia (Oreochromis spp.) in Taiwan, 2016–2018. Journal of Fish Diseases, 44(3), 321–333. https://doi.org/10.1111/jfd.13296

Carson, J., Wilson, T., Douglas, M., & Barnes, A. (2019). Yersiniosis in fish (Australian and New Zealand Standard Diagnostic Procedures). Department of Primary Industries and Water, Centre for Aquatic Animal Health and Vaccines. https://www.agriculture.gov.au/sites/default/files/documents/anzsdp-yersiniosis_0.pdf

Castañeda, A. E., Toledo, O. E., Feria, M., Zatan, A. E., Aguilar, J. L., & Jara, L. M. (2025). Frecuencia de patógenos bacterianos y virales en peces de cultivo a partir de un laboratorio acuícola en Piura, Perú, durante el 2020–2023. Revista de Investigaciones Veterinarias del Perú, 36(3), e28876. https://doi.org/10.15381/rivep.v36i3.28876

Cipriano, R. C. (2005). Intraovum infection caused by *Flavobacterium psychrophilum* among eggs from captive Atlantic salmon broodfish. Journal of Aquatic Animal Health, 17(3), 275–283. https://doi.org/10.1577/H05-003.1

Cipriano, R. C., & Holt, R. A. (2005a). *Flavobacterium psychrophilum*, cause of bacterial cold-water disease and rainbow trout fry syndrome. Kearneysville, West Virginia: US Department of the Interior, US Geological Survey, National Fish Health Research Laboratory.

Cipriano, R. C., & Holt, R. A. (2005b). *Flavobacterium psychrophilum*, cause of bacterial cold-water disease and rainbow trout fry syndrome (Fish Disease Leaflet No. 86). U.S. Department of the Interior,U.S. Geological Survey. https://freshwater-aquaculture.extension.org/wp-content/uploads/2019/08/USFWS_Coldwater_disease.pdf

Cook, M., & Lynch, W. H. (1999). A sensitive nested reverse transcriptase PCR assay to detect viable cells of the fish pathogen *Renibacterium salmoninarum* in Atlantic salmon (Salmo salar L.). Applied and Environmental Microbiology, 65(7), 3042–3047. https://doi.org/10.1128/AEM.65.7.3042-3047.1999

Dalsgaard, I., Bruun, M. S., Andersen, J. H., & Madsen, L. (2009). Recent knowledge of *Flavobacterium psychrophilum* in Denmark. In Flavobacterium 2009 Scientific Program + Proceedings (2nd Conference on Members of the Genus

Flavobacterium, Paris, France 2123, (Sept.2009). Disponible en https://colloque2.inra.fr/flavobacterium_eng/actualites/programme_scientifique_ proceedings

Das, B. K., & Dong, H. (2024). Pathological effects and immune modulation in host during bacterial and parasitic infections of aquatic animals: A review focusing on tilapia in China. Scientific Reports, 14, 7945. https://doi.org/10.1038/s41598-024- 79089-5

Declercq, A. M., Haesebrouck, F., Van den Broeck, W., Bossier, P., & Decostere, A. (2013). Columnaris disease in fish: A review with emphasis on bacterium–host interactions. Veterinary Research, 44, 27. https://doi.org/10.1186/1297-9716-44- 27

Delghandi, M. R., El-Matbouli, M., & Menanteau-Ledouble, S. (2020). *Renibacterium salmoninarum*—the causative agent of bacterial kidney disease in salmonid fish. Pathogens, 9(10), 845.

Deng, F., Liu, X., Zhou, Y., … Zhang, Q. (2024). Systemic immune response of rainbow trout exposed to *Flavobacterium psychrophilum* infection. Fish & Shellfish Immunology, 140, 109305. https://doi.org/10.1016/j.fsi.2023.109305

Dietrich, J. P., Boylen, D. A., Thompson, D. E., Loboschefsky, E. J., Bravo, C. F., Spangenberg, D. K., Ylitalo, G. M., Collier, T. K., Fryer, D. S., Arkoosh, M. R., & Loge, F. J. (2011). An evaluation of the influence of stock origin and out-migration history on the disease susceptibility and survival of juvenile Chinook salmon. Journal of Aquatic Animal Health, 23(1), 35–47. https://doi.org/10.1080/08997659.2011.568859

Dils, R. E., Firestone, T. B. R., Schaffer, P. A., Winkelman, D. L., & Fetherman, E. R. (2025). Histological progression and bacterial load dynamics of *Renibacterium salmoninarum* in Chinook salmon Oncorhynchus tshawytscha. Diseases of Aquatic Organisms, 162, 85–97. https://doi.org/10.3354/dao03852

Doan, T. N., Dang, T. H., Tran, T. T., Mai, V. T., Nguyen, T. H. G., Kim, V. V., & Truong, D. H. (2025). First insights into *Weissella tructae* infections in rainbow trout (*Oncorhynchus mykiss*) in Viet Nam: Bacterial characterization, pathogenicity and antimicrobial susceptibility. Aquaculture Reports, 43, 102955. https://doi.org/10.1016/j.aqrep.2025.102955

Dong, H. T., Siriroob, S., Meemetta, W., Santimanawong, W., Gangnonngiw, W., Pirarat, N., Khunrae, P., Rattanarojpong, T., Vanichviriyakit, R., & Senapin, S. (2017). Emergence of tilapia lake virus in Thailand and an alternative semi-nested RT-PCR for detection. Aquaculture, 476, 111–118. https://doi.org/10.1016/j.aquaculture.2017.04.019

Dopazo, C. P. (2020). The infectious pancreatic necrosis virus (IPNV) and its virulence determinants: What is known and what should be known. Pathogens, 9(2), 94. https://doi.org/10.3390/pathogens9020094

Doumayrou, J., Ryan, M. G., & Wargo, A. R. (2019). Method for serial passage of infectious hematopoietic necrosis virus (IHNV) in rainbow trout. Diseases of Aquatic Organisms, 134, 223-236. https://doi.org/10.3354/dao03368

Droshnev, A. E., Bulina, K. Y., Alontseva, D. A., Belimenko, V. V., & Zavyalova, E. A. (2019). Microbiological monitoring of causative agents of infectious diseases of salmons in the Northwest region. IOP Conference Series: Earth and Environmental Science, 315(7), 072007. https://doi.org/10.1088/1755-1315/315/7/072007

Duan, K., Zhao, J., Ren, G., Shao, Y., Lu, T., Xu, L., Tang, X., Zhao, W., & Xu, L. (2021). Molecular evolution of infectious pancreatic necrosis virus in China. Viruses, 13(3), 488. https://doi.org/10.3390/v13030488

Ekman, E., Börjeson, H., & Johansson, N. (1999). *Flavobacterium psychrophilum* in Baltic salmon *Salmo salar* brood fish and their offspring. Diseases of Aquatic Organisms, 37(3), 159-163. https://doi.org/10.3354/dao037159

Fathi, M., Dickson, C., Dickson, M., Leschen, W., Baily, J., Muir, F. & Weidmann, M. (2017). Identification of Tilapia Lake Virus in Egypt in Nile tilapia affected by 'summer mortality' syndrome. Aquaculture, 473, 430-432. https://doi.org/10.1016/j.aquaculture.2017.03.014

Fetherman, E. R., Neuschwanger, B., Davis, T., Wells, C. L., & Kraft, A. (2020). Efficacy of Erymicin 200 Injections for Reducing *Renibacterium salmoninarum* and Controlling Vertical Transmission in an Inland Rainbow Trout Brood Stock. Pathogens (Basel, Switzerland), 9(7), 547.https://doi.org/10.3390/pathogens9070547

Fisheries and Oceans Canada. (2017). Residual infectious pancreatic necrosis (IPN) transmission risk from Arctic char transfers into British Columbia (Science Response 2017/041). Canadian Science AdvisorySecretariat. https://publications.gc.ca/collections/collection_2017/mpo-dfo/Fs70-7-2017-041- eng.pdf

Florez-Jalixto, M. A., & Roldán-Acero, D. J. (2021). La trucha (*Oncorhynchus mykiss*): Potenciales productos alimenticios derivados del principal recurso acuícola en regiones altoandinas [Rainbow trout (Oncorhynchus mykiss): Potential food products derived from the main aquaculture resource in high-Andean regions]. Revista De Investigaciones Altoandinas - Journal of High Andean Research, 23(3), 159-170. https://doi.org/10.18271/ria.2021.279

Food and Agriculture Organization of the United Nations (FAO) 2023. (n.d.). Fisheries and aquaculture statistics. Retrieved September 8, 2025, from https://www.fao.org/fishery/en/statistics

Food and Agriculture Organization of the United Nations (FAO). (2023). The Progressive Management Pathway for Aquaculture Biosecurity (PMP/AB): Guidelines for application (FAO Fisheries and Aquaculture Technical Paper No. 689). FAO. https://openknowledge.fao.org/items/0b68ac38-6ec0-4938-8691-3e082ae3ac35

Food and Agriculture Organization of the United Nations (FAO). (2024a). The State of World Fisheries and Aquaculture 2024: Blue transformation in action. FAO. https://doi.org/10.4060/cd0683en

Food and Agriculture Organization of the United Nations (FAO). (2025a). Aquatic species. Retrieved September 8, 2025, from https://www.fao.org/fishery/en/collection/aqspecies

Food and Agriculture Organization of the United Nations (FAO). (2025b). Fishery and aquaculture country profiles. Retrieved September 8, 2025, from https://www.fao.org/fishery/en/collection/facp

Food and Agriculture Organization of the United Nations (FAO). (2025c). Fishery and Aquaculture Statistics: Yearbook 2022. FAO. https://doi.org/10.4060/cd4312en

Fusianto, C., Hick, P. M., Herlambang, A., Whittington, R. J., & Becker, J. A. (2021). Outbreak investigation attributes Infectious spleen and kidney necrosis virus as a necessary cause of a mortality epidemic in farmed grouper (Epinephelus spp.) in Bali, Indonesia. Aquaculture Reports, 20, 100723. https://doi.org/10.1016/j.aqrep.2021.100723

Gallardo Lagno, A., Lara, M., & Cornejo, J. (2024). Aquatic animal health: History, present and future. Revue Scientifique et Technique (International Office of Epizootics), Special Edition, 152–158. https://doi.org/10.20506/rst.SE.3570

Gnanagobal, H., Cao, T., Hossain, A., Dang, M., Hall, J. R., Kumar, S., Van Cuong, D., Boyce, D., & Santander, J. (2021). Lumpfish (*Cyclopterus lumpus*) Is Susceptible to *Renibacterium salmoninarum* Infection and Induces Cell-Mediated Immunity in the Chronic Stage. Frontiers in Immunology, 12, 733266. https://doi.org/10.3389/fimmu.2021.733266

Godoy, M. G. (2013). Enfermedad columnaris (*Flavobacterium columnare*) en trucha arcoíris (*Oncorhynchus mykiss*): I. Patología macroscópica [Columnaris disease (*Flavobacterium columnare*) in rainbow trout (*Oncorhynchus mykiss*): I. Gross pathology]. Informe/nota técnica de patología de peces.

Godoy, M. G., Kibenge, M. J. T., Montes de Oca, M., Pontigo Díaz, J. P., Coca, Y., Caro, D., Kusch, K., Suarez, R., Burbulis, I., & Kibenge, F. S. B. (2022). Isolation of a new infectious pancreatic necrosis virus (IPNV) variant from genetically resistant farmed Atlantic salmon (*Salmo salar*) during 2021–2022. Pathogens, 11(11), 1368. . https://doi.org/10.3390/pathogens11111368

Grano-Maldonado, M. I., Rodríguez-Santiago, M. A., García-Vargas, F., Nieves- Soto, M., & Soares, F. (2018). Una infección emergente causada por *Gyrodactylus cichlidarum* Paperna, 1968 (Monogenea: Gyrodactylidae) asociada con una mortalidad masiva en tilapia *Oreochromis niloticus* (L.) de cultivo en la costa del Pacífico mexicano. Revista Latinoamericana de Investigaciones Acuáticas, 46(5), 961–968. https://doi.org/10.3856/vol46-issue5-fulltext-9

Guo, C., He, J., Xu, X., Weng, S., & He, J. (2025). Megalocytivirus: A Review of Epidemiology, Pathogenicity, Immune Evasion, and Prevention Strategies. Reviews in Aquaculture, 17(3), e70025. https://doi.org/10.1111/raq.70025

Haenen, O. L. M., Mohan, C. V., Soto, E., Mast, J., van der Marel, M., van Muiswinkel, W. B., & Michel, C. (2023). Bacterial diseases of tilapia, their zoonotic potential and control strategies. Reviews in Aquaculture, 15(4), 1900–1925. https://doi.org/10.1111/raq.12743

He, J., Yu, Y., Li, Z. M., Liu, Z. X., Weng, S. P., Guo, C. J., & He, J. G. (2022). Hypoxia triggers the outbreak of infectious spleen and kidney necrosis virus disease through viral hypoxia response elements. Virulence, 13(1), 714-726. https://doi.org/10.1080/21505594.2022.2065950

Hernández-Hernández, M., García-Márquez, L., Gutiérrez-Jiménez, J., Feliciano- Guzmán, J., López-Santiz, R., & Bautista-Trujillo, G. (2023). Oreochromis niloticus exhibe una prevalencia mayor de Streptococcus beta hemolítico cuando se mantienen en jaulas en comparación con estanques. Abanico Veterinario, 13, e2022-32. https://doi.org/10.21929/abavet2023.19

Hesami, S., Allen, K. J., Metcalf, D., Ostland, V. E., MacInnes, J. I., & Lumsden, J.S. (2008). Phenotypic and genotypic analysis of Flavobacterium psychrophilum isolates from Ontario salmonids with bacterial coldwater disease. Canadian Journal of Microbiology, 54(8), 619–629. https://doi.org/10.1139/W08-058

Holopainen, R., Eriksson-Kallio, A.-M., & Gadd, T. (2017). Molecular characterisation of infectious pancreatic necrosis viruses isolated from farmed fish in Finland. Archives of Virology, 162(11), 3459–3471. https://doi.org/10.1007/s00705-017-3493-9

Honeyfield, D. C., Elliott, R. F., Fitzsimons, J. D., & Tillitt, D. E. (2015). Presence of the BKD-causing bacterium Renibacterium salmoninarum in lake whitefish and bloaters in the Laurentian Great Lakes. Journal of Great Lakes Research, 41(3), 912–918. https://doi.org/10.1016/j.jglr.2015.05.010

Ivanov, V. V., & Sidorova, N. V. (2022). Aeromonas infections in salmonid aquaculture in Russia: Pathogenesis and control strategies. Journal of Fish Diseases, 45(12), 1783–1795. https://doi.org/10.1111/jfd.13721

Janda, J. M., & Duman, M. (2024). Expanding the spectrum of diseases and disease associations caused by Edwardsiella tarda and related species. Microorganisms, 12(5), 1031. https://doi.org/10.3390/microorganisms12051031

Jonas, J. L., Schneeberger, P. J., Clapp, D. F., Wolgamood, M., Wright, G., & Lasee, B. (2002). Presence of the BKD-causing bacterium Renibacterium salmoninarum in lake whitefish and bloaters in the Laurentian Great Lakes. Advances in Limnology 55, 447–452. https://www.researchgate.net/publication/289661007_Presence_of_the_BKD causing_bacterium_Renibacterium_salmoninarum_in_lake_whitefish_and_bl oater s_in_the_Laurentian_Great_Lakes -

Karga, M. (2025). Effects of some common bacterial fish diseases on fish behavior in aquaculture: a Review: Influence of bacterial diseases on fish behavior. Marine Reports (Marep), 4(1), 68-79. https://doi.org/10.5281/zenodo.15764098

Kembou-Ringert, J. E., Steinhagen, D., Readman, J., Daly, J. M., & Adamek, M. (2023). Tilapia Lake Virus vaccine development: A review on the recent advances. Vaccines, 11(2), 251. https://doi.org/10.3390/vaccines11020251

Kim, H. J., Olesen, N. J., Dale, O. B., Kim, Y. C., Jung, T. S., Vendramin, N., & Kwon, S. R. (2023). Pathogenicity of two lineages of infectious hematopoietic necrosis virus (IHNV) to farmed rainbow trout (*Oncorhynchus mykiss*) in Korea. Virus Research, 332, 199133. https://doi.org/10.1016/j.virusres.2023.199133

Klug, J. J., Treuting, P. M., Sanders, G. E., Winton, J. R., & Kurath, G. (2021). Effects of stocking density on stress response and susceptibility to infectious hematopoietic necrosis virus in rainbow trout. Journal of the American Association for Laboratory Animal Science, 60(6), 637-645. https://doi.org/10.30802/AALAS- JAALAS-21-000003

Ko, Y.-M., & Heo, G.-J. (1997). Characteristics of *Flavobacterium branchiophilum* isolated from rainbow trout in Korea. Fish Pathology, 32(2), 97–102. https://doi.org/10.3147/jsfp.32.97

Koh, T. H., Kurup, A., & Chen, J. (2004). *Streptococcus iniae* discitis in Singapore. Emerging Infectious Diseases, 10(9), 1694–1696. https://doi.org/10.3201/eid1009.040029

Kong, K.-H., Gong, I.-H., Jung, S.-J., Oh, M.-J., Jung, M.-H., Han, H.-J., Kim, H.- J., & Kim, W.-S. (2024). First report of bacterial kidney disease (BKD) caused by *Renibacterium salmoninarum* in chum salmon (*Oncorhynchus keta*) farmed in South Korea.Microorganisms, 12, 2329. https://doi.org/10.3390/microorganisms12112329

Kumagai, A., Takahashi, K., Yamaoka, S., & Wakabayashi, H. (1998). Ineffectiveness of iodophore treatment in disinfecting salmonid eggs carrying *Cytophaga psychrophila*. Fish Pathology, 33(3), 123-128.

Kurniawan, S. B., Ahmad, A., Rahim, N. F. M., Said, N. S. M., Alnawajha, M. M., Imron, M. F., Abdullah, S. R. S., Othman, A. R., Ismail, N. I., & Hasan, H. A. (2021). Aquaculture in Malaysia: Water-related environmental challenges and opportunities for cleaner production. Environmental Technology and Innovation, 24, 101913. https://doi.org/10.1016/j.eti.2021.101913

LaFrentz, B.R., Kralova, S., Burbick, C.R., Alexander, T.L., Phillips, C.W., Griffin, M.J., Waldbieser, G.C. *et al*. 2022. The fish pathogen *Flavobacterium columnare* represents four distinct species: *Flavobacterium columnare*, *Flavobacterium covae* sp.nov.,*Flavobacteriumdavisii*sp.nov.and*Flavobacterium oreochromis*sp.nov., and emended description of *Flavobacterium columnare*. Systematic and Applied Microbiology, 45(2): 126293. https://doi.org/10.1016/j.syapm.2021.126293

Lam, Z. (2023). Fish disease in Hong Kong aquaculture [Conference abstract]. World Aquaculture Society. https://www.was.org/MeetingAbstracts/ShowAbstract/83053

Lehmann, J. D. F. J., Mock, D., Stiirenberg, F. J., & Bernardet, J. F. (1991). First isolation of *Cytophaga psychrophila* from a systemic disease in eel and cyprinids. Diseases of Aquatic Organisms, 10, 217-220.

León, J., Ávalos, R., & Ponce, M. (2009). *Flavobacterium psychrophilum* y su patología en alevines de *Oncorhynchus mykiss* del Centro Piscícola El Ingenio, Huancayo. Revista Peruana de Biología, 15(2), 117–124. https://www.redalyc.org/pdf/1950/195018674019.pdf

Li, C., Tse, H., Zhu, C., Choi, G. K. Y., Lee, A. L.-H., Yang, J., Lo, N. W.-S., Hui, D. T.-Y., Chow, C. K.-Y., Chau, S. K.-Y., Lam, J., Luk, K., Que, T.-L., Fung, K. S.-C., Tse, C., Wong, S. C.-Y., Lung, D. C., Chow, V. C.-Y., & Ip, M. (2025). Invasive group B Streptococcus infections caused by hypervirulent clone of S. agalactiae sequence type 283, Hong Kong, China, 2021. Emerging Infectious Diseases, 31(1), 149–154. https://doi.org/10.3201/eid3101.231627

Li, Y., Li, W., Yang, Q., He, Y., Liu, J., Ma, Y., Li, S., Zhou, Y., Li, Q., Huang, X., Chen, D., Geng, Y., Wei, W., & Ouyang, P. (2024). Isolation, identification, and molecular evolutionary analysis of infectious hematopoietic necrosis virus (IHNV) from farmed rainbow trout in Southwest China. Israeli Journal of Aquaculture – Bamidgeh, 76(4), 189–201. https://doi.org/10.46989/001c.124903

Lida, Y., & Mizokami, A. (1996). Outbreaks of cold-water disease in wild ayu and pale chub. Fish Pathology, 31(3), 157–164.

Madetoja, J., Nystedt, S., & Wiklund, T. (2003). Survival and virulence of *Flavobacterium psychrophilum* in water microcosms. Fems Microbiology Ecology, 43(2), 217-223. https://doi.org/10.1111/j.1574-6941.2003.tb01061.x

Martínez-Lara, P., Martínez-Porchas, M., Gollas-Galván, T., Hernández-López, J., & Robles-Porchas, G. R. (2021). Granulomatosis in fish aquaculture: A mini review. Reviews in Aquaculture, 13(1), 259–268. https://doi.org/10.1111/raq.12472

Marsella, A., Buratin, A., Pascoli, F., Abbadi, M., Toson, M., Cuenca, A., & Vendramin, N. (2025). Temperature impact on replication and virulence of European infectious hematopoietic necrosis viruses. Aquaculture, 742786.

Medina, M., Fernandez-Espinel, C., Sotil, G., Yunis-Aguinaga, J., & Flores-Dominick, V. (2020). First description *of Weissella ceti*associated with mortalities in farmed rainbow trout (*Oncorhynchus mykiss*) in Peru. Aquaculture, 529, 735608. https://doi.org/10.1016/j.aquaculture.2020.735608.

Mesías V, Fernando, Vargas L, Mario, Cueva Q, Alexander, Manchego S, Alberto, & Sandoval C, Nieves. (2019). Patogenicidad de una cepa de *Yersinia ruckeri* de un brote de yersiniosis en truchas arcoíris (*Oncorhynchus mykiss*) de Huaraz, Perú. Revista de Investigaciones Veterinarias del Perú, 30(1), 387-403. http://www.scielo.org.pe/scielo.php?script=sci_arttext&pid=S1609-91172019000100039

Mqolomba, T. N., & Plumb, J. (1992). Effect of temperature and dissolved oxygen concentration on *Edwardsiella ictaluri* in experimentally infected channel catfish. Journal of Aquatic Animal Health, 4, 215–217. https://doi.org/10.1577/1548- 8667(1992)004<0215: EOTADO>2.3.CO;2

Mutoloki, S., Torfoss, V., & Evensen, Ø. (2016). Infectious pancreatic necrosis virus causing clinical and subclinical infections in Atlantic salmon have different genetic fingerprints. Journal of Fish Diseases, 39(3), 387–400. https://doi.org/10.1111/jfd.12368

Nematollahi, A., Decostere, A., Pasmans, F., & Haesebrouck, F. (2003). *Flavobacterium psychrophilum* infections in salmonid fish. Journal of Fish Diseases, 26(10), 563-574. https://doi.org/10.1046/j.1365-2761.2003.00488.x

Network of Aquaculture Centres in Asia-Pacific (NACA). (2024). Quarterly Aquatic Animal Disease Report (QAAD), Asia–Pacific region, 2024 (Vol. 47). NACA. https://www.naca.org

Nhinh, D. T., Giang, N. T. H., Van Van, K., Dang, L. T., Dong, H. T., & Hoai, T. D. (2022). Widespread presence of a highly virulent *Edwardsiella ictaluri* strain in farmed tilapia (Oreochromis spp.). Transboundary and Emerging Diseases, 69(5), e2276–e2290. https://doi.org/10.1111/tbed.14568

Nielsen, S. S., Alvarez, J., Calistri, P., Canali, E., Drewe, J. A., & Bicout, D. J. (2023). Assessment of listing and categorisation of animal diseases within the framework of the Animal Health Law (Regulation (EU) 2016/429): infection with *Gyrodactylus salaris* (GS). Efsa Journal, 21(10).

Nishiki, I., Furukawa, M., Matui, S., Itami, T., Nakai, T., & Yoshida, T. (2011). Epidemiological study on *Lactococcus garvieae* isolates from fish in Japan. Fisheries Science, 77(3), 367–373. https://doi.org/10.1007/s12562-011-0332-0

Nuñure, J. O., Sandoval, N., Estrella, M. O., Ramos, F. E., Herrera, A., Valera, A., & Manchego, A. (2021). Identificación y caracterización de Aeromonas sp. patógenas aisladas de truchas arcoíris (Oncorhynchus mykiss) clínicamente enfermas cultivadas en piscigranjas del Perú. Revista de Investigaciones Veterinarias del Perú, 32(4), e20927. https://doi.org/10.15381/rivep.v32i4.20927

Oh, W. T., Jun, J. W., Giri, S. S., Yun, S., Kim, H. J., Kim, S. G., Kim, S. W., Kang, J. W., Han, S. J., Kwon, J., Kim, J. H., Smits, T. H. M., & Park, S. C. (2019). Pseudomonas tructae sp. nov., novel species isolated from rainbow trout kidney. International Journal of Systematic and Evolutionary Microbiology, 69(12),3851–3856. https://www.microbiologyresearch.org/docserver/fulltext/ijsem/69/12/3851_ijsem003696.pdf?expires=1761511002&id=id&accname=guest&checksum=19F9E6C AF3FCD4EF996B8D9FA162046A

Oh, W. T., Jun, J. W., Kim, H. J., Giri, S. S., Yun, S., Kim, S. G., Kim, S. W., Kang, J. W., Han, S. J., Kwon, J., & Park, S. C. (2020). Characterization and pathological analysis of a virulent Edwardsiella anguillarum strain isolated from Nile tilapia (Oreochromis niloticus) in Korea. Frontiers in Veterinary Science, 7, 14. https://doi.org/10.3389/fvets.2020.00014

Oidtmann, B., Dixon, P., Way, K., Joiner, C., & Bayley, A. (2018). Risk of waterborne virus spread – Review of survival of relevant fish and crustacean viruses in the aquatic environment and implications for control measures. Reviews in Aquaculture, 10(3), 641–669. https://doi.org/10.1111/raq.12169

Okasha, L. A., Farag, E. A., Sayed-ElAhl, R. M., & Sherif, A. H. (2025). Presence of virulent Edwardsiella tarda in farmed nile tilapia and striped catfish. Bmc Microbiology, 25(1), 572. https://doi.org/10.1186/s12866-025-04232-9

Oplinger, R. W., & Wagner, E. J. (2015). Use of penicillin and streptomycin to reduce spread of bacterial coldwater disease I: antibiotics in sperm extenders. Journal of Aquatic Animal Health, 27(1), 25-31. https://doi.org/10.1080/08997659.2014.966211

Organismo Nacional de Sanidad Pesquera (SANIPES). (2023a). Infección por Streptococcus agalactiae en tilapia. Ministerio de la Producción, Gobierno del Perú. https://www.gob.pe/institucion/sanipes/campanas/110807-infeccion-por-streptococcus-agalactiae

Organismo Nacional de Sanidad Pesquera (SANIPES). (2023b). Plan de emergencia para el virus de la tilapia del lago (TiLV). Ministerio de la Producción, Gobierno del Perú. https://www.sanipes.gob.pe/tilapia/Plan-Emergencia-TiLV.pdf

Organismo Nacional de Sanidad Pesquera (SANIPES). (2024). Vigilancia de enfermedades de notificación obligatoria en peces cultivados: Necrosis pancreática infecciosa (IPN). Ministerio de la Producción, Gobierno del Perú. https://www.sanipes.gob.pe/vnpi/

Ortega, C., Mancera, G., Enríquez, R., Vargas, A., Martínez, S., Fajardo, R., Avendaño-Herrera, R., Navarrete, M. J., & Romero, A. (2016). First identification of *Francisella noatunensis* subsp. orientalis causing mortality in Mexican tilapia (Oreochromis spp.). Diseases of Aquatic Organisms, 120(3), 205–215. https://doi.org/10.3354/dao02999

Persson, B. D., Aspán, A., Hysing, P., Blomkvist, E., Jansson, E., Orsén, L., Hällbom, H., & Axén, C. (2022). Assessing the presence and spread of *Renibacterium salmoninarum* between farmed and wild fish in Sweden. Journal of Fish Diseases, 45(5), 613–621. https://doi.org/10.1111/jfd.13586

Pingping Wang, J., Ji, J., & Zhang, Y. (2020). Aquaculture extension system in China: Development, challenges, and prospects. Aquaculture Reports, 17, 100339. https://doi.org/10.1016/j.aqrep.2020.100339

Ponsrinivasan, A., Uma, A., Chidambaram, P., Antony, C., Sudhagar, A., Selvaraj, S., & Ethirajan, M. (2025). Environmental variability and pathogen synergy influencing tilapia lake virus outbreaks on tilapia farms in Tamil Nadu, India. Archives of Virology, 170(7), 162. https://doi.org/10.1007/s00705-025-06355-w

Pulido, A., Iregui, C., Figueroa, J., & Klesius, P. (2004). Estreptococosis en tilapias (*Oreochromis* spp.) cultivadas en Colombia [Streptococcosis in tilapia (*Oreochromis* spp.) farmed in Colombia]. Revista Aquatic, 20, 97-106. https://www.redalyc.org/pdf/494/49402010.pdf

Purcell, M.K., McKibben, C.L., Pearman-Gillman, S., Elliott, D.G. and Winton, J.R. (2016), Effects of temperature on *Renibacterium salmoninarum* infection and transmission potential in Chinook salmon, Oncorhynchus tshawytscha (Walbaum). J Fish Dis, 39: 787-798. https://doi.org/10.1111/jfd.12409

Quek, C. C., Haryanto, A., & Kristianingrum, Y. P. (2020). Detection of *Aeromonas hydrophila* infection on tilapia fish (*Oreochromis niloticus*) skin by hematoxylin-eosin and immunohistochemistry staining. Indonesian Journal of Veterinary Sciences, 1(2), 55–59. https://jurnal.ugm.ac.id/ijvs/article/view/64037

Reichley, S. R., Ware, C., Steadman, J., Gaunt, P. S., García, J. C., LaFrentz, B. R., Thachil, A., Waldbieser, G. C., Stine, C. B., Buján, N., Arias, C. R., Loch, T., Welch, T. J., Cipriano, R. C., Greenway, T. E., Khoo, L. H., Wise, D. J., Lawrence, M. L., & Griffin, M. J. (2017). Comparative phenotypic and genotypic analysis of Edwardsiella isolates from different hosts and geographic origins, with emphasis on isolates formerly classified as E. tarda, and evaluation of diagnostic methods. Journal of Clinical Microbiology, 55(12), 3466–3491. https://doi.org/10.1128/JCM.00970-17

Ridzuan, M. S. M., Abdullah, A., Ramly, R., Mansor, N. N., Ramli, N., & Firdaus-Nawi, M. (2022). Current status and advances of fish vaccines in Malaysia. Veterinary World, 15(2), 465–482. https://doi.org/10.14202/vetworld.2022.465-482

Roberts, R. J., & Pearson, M. D. (2005). Infectious pancreatic necrosis in Atlantic salmon, Salmo salar L. Journal of Fish Diseases, 28(7), 383–390. https://doi.org/10.1111/j.1365-2761.2005.00642.x

Rozas-Serri, M., Caballero-Celli, R., Jaramillo, V., Ildefonso, R., Velazco-Peña, R., Rodriguez-Callan, J., Ulloa-Stanojlovic, F., & Gómez-Sánchez, M. (2025). Piscine orthoreovirus genotype 3b (PRV-3b) in rainbow trout (*Oncorhynchus mykiss*) farmed in Peru: First detection in Lake Titicaca. SSRN. https://doi.org/10.2139/ssrn.5127572

Ruane, N. M., McCarthy, L. J., Swords, D., Henshilwood, K., & McLoughlin, M. F. (2009). Molecular differentiation of infectious pancreatic necrosis virus isolates from farmed and wild salmonids in Ireland, 2003–2007. Journal of Fish Diseases, 32(12), 1091–1105. https://doi.org/10.1111/j.1365-2761.2009.01091.x

Saksmerprome, V., Jitrakorn, S., Dekham, K., Phumiphanjarphak, W., Thompson, K. D., Costa, J., Metselaar, M., Ounjai, P., & Aiewsakun, P. (2025).

Identification and characterisation of a lethal infectious spleen and kidney necrosis virus (ISKNV) from Indonesian Nile tilapia samples. Journal of Fish Diseases. https://doi.org/10.1111/jfd.70038

Salgado-Miranda, C., Rojas-Anaya, E., García-Espinosa, G., & Loza-Rubio, E. (2020). Virulence of infectious pancreatic necrosis virus (IPNV) isolates from Mexico. Journal of Veterinary Medical Science, 82(3), 394–398. https://doi.org/10.1292/jvms.18-0737

Sapugahawatte, D. N., Li, C., Dharmaratne, P., Zhu, C., Yeoh, Y. K., Yang, J., Lo, N. W. S., Wong, K. T., & Ip, M. (2022). Prevalence and characteristics of *Streptococcus agalactiae* from freshwater fish and pork in Hong Kong wet markets. Antibiotics, 11(3), 397. https://doi.org/10.3390/antibiotics11030397

Seafood Watch. (2023, July 10). Rainbow trout (*Oncorhynchus mykiss*) – Chile: Freshwater raceways (Report ID 28292). Monterey Bay Aquarium. https://www.seafoodwatch.org/recommendations/our-standards

Secades, P., Alvarez, B., & Guijarro, J. A. (2001). Purification and characterization of a psychrophilic, calcium-induced, growth-phase-dependent metalloprotease from the fish pathogen *Flavobacterium psychrophilum*. Applied and Environmental Microbiology, 67(6), 2436-2444. https://doi.org/10.1128/AEM.67.6.2436-2444.2001

Servicio Nacional de Pesca y Acuicultura (SERNAPESCA). (2024). Informe sobre el uso de antimicrobianos y antiparasitarios en la salmonicultura nacional. Año 2023. Ministerio de Economía, Fomento y Turismo, Gobierno de Chile. https://www.sernapesca.cl/app/uploads/2024/06/Informe-sobre-el-uso-de-antimicrobianos-y-antiparasitarios-en-la-salmonicultura-nacional-Ano-2023_v20240606.pdf?

Silva, Y. R., & Austin, B. (2017). *Yersinia ruckeri* and enteric redmouth disease (ERM) in fish: A review. Veterinary Research, 48(1), 1–26. https://doi.org/10.1186/s13567-015-0238-4

Skjesol, A., Aamo, T., Hegseth, M. N., Robertsen, B., & Jørgensen, J. B. (2011). IPNV with high and low virulence: Host immune responses and viral mutations during infection. Virology Journal, 8, 396. https://doi.org/10.1186/1743-422X-8-396

Smail, D. A., & Munro, E. S. (2008). Isolation and quantification of infectious pancreatic necrosis virus from ovarian and seminal fluids of Atlantic salmon, *Salmo salar* L. Journal of Fish Diseases, 31(1), 49–58. https://doi.org/10.1111/j.1365- 2761.2007.00875.x

Smith, S. A. (2019). Fish diseases and medicine. CRC Press.

Song, H., Santi, N., Evensen, Ø., & Vakharia, V. N. (2005). Molecular determinants of infectious pancreatic necrosis virus virulence and cell culture adaptation. Journal of Virology, 79(16), 10289–10299.https://doi.org/10.1128/JVI.79.16.10289-10299.2005

Starliper, C. E. (2011). Bacterial coldwater disease of fishes caused by *Flavobacterium psychrophilum*. Journal of Advanced Research, 2(2), 97-108. https://doi.org/10.1016/j.jare.2010.04.001

Stenton-Dozey, J. M., Heath, P., Ren, J. S., & Zamora, L. N. (2020). Industria acuícola de Nueva Zelanda: Investigación, oportunidades y limitaciones para la acuicultura multitrófica integradora. New Zealand Journal of Marine and Freshwater Research, 55(2), 265–285. https://doi.org/10.1080/00288330.2020.1752266

Suebsing, R., Kim, J. H., Kim, S. R., Park, M. A., & Oh, M. J. (2011). Detection of viruses in farmed rainbow trout (Oncorhynchus mykiss) in Korea by RT-LAMP assay. Journal of Microbiology, 49(5), 741–746. https://doi.org/10.1007/s12275- 011-1209-8

Suebsing, R., Pradeep, P. J., Jitrakorn, S., Sirithammajak, S., Kampeera, J., Turner, W. A., & Kiatpathomchai, W. (2016). Detection of natural infection of infectious spleen and kidney necrosis virus in farmed tilapia by hydroxynapthol blue-loop- mediated isothermal amplification assay. Journal of Applied Microbiology, 121(1), 55–67. https://doi.org/10.1111/jam.13165

Sule, H. A., Saba, A. O., & Yu, C. Y. (2025). Streptococcosis in aquaculture: Advances, challenges, and future directions in disease control and prevention. arXiv preprint arXiv:2510.27354.

Surachetpong, W., Janetanakit, T., Nonthabenjawan, N., Tattiyapong, P., Sirikanchana, K., & Amonsin, A. (2017). Outbreaks of tilapia lake virus infection, Thailand, 2015–2016. Emerging Infectious Diseases, 23(6), 1031–1033. https://doi.org/10.3201/eid2306.161278

Suzuki, K., Mizuno, S., Katsumata, Y., Misaka, N., Miyamoto, M., & Sasaki, Y. (2018). Asymptomatic Infection of *Renibacterium salmoninarum* in Hatchery-reared Juvenile Chum Salmon Oncorhynchus keta Resulted in Mass Mortalities after Long-term Rearing. Fish Pathology, 53(1), 40–43. https://doi.org/10.3147/JSFP.53.40

Svobodova, Z., Lloyd, R., Máchová, J., & Vykusová, B. (1993). Water quality and fish health. Rome: FAO. https://www.fao.org/4/t1623e/T1623E00.html

Tahiluddin, A. B., & Terzi, E. (2021). A review of reported bacterial diseases and antibiotic use in tilapia culture in the Philippines. Acta Natura et Scientia, 2(2), 141–147. https://doi.org/10.29329/actanatsci.2021.350.08

Takeuchi, H., Hiratsuka, M., Hori, K., Oinuma, H., Umino, Y., Nakano, D., & Mano, N. (2021). Environmental factors affecting *Edwardsiella ictaluri*-induced mortality of riverine ayu, Plecoglossus altivelis (Temminck & Schlegel). Journal of Fish Diseases, 44(8), 1065-1074. https://doi.org/10.1111/jfd.13368

Tapia, D., Gomez-Uchida, D., Garin-Fernandez, A., Yáñez, J. M., Eissler, Y., &

Canales-Aguirre, C. B. (2025). Viral Pathogens in Free-Living Salmonids: Aquaculture and Ecosystem Implications. Reviews in Aquaculture, 17(2). https://doi.org/10.1111/raq.70007

Taukhid, T., Lusiastuti, A. M., Novita, H., Caruso, D., Avarre, J.-C., Sugiani, D., Kholidin, E. B., Saputra, A., Widyastuti, Y. R., & Andriyanto, S. (2024). Resistance of Indonesian tilapia strains, *Oreochromis niloticus*, to Tilapia Lake Virus Disease (TiLVD). Bulletin of the European Association of Fish Pathologists, 44(1). https://doi.org/10.48045/001c.118454.

Taukhid, T., Wajdy, E. F., Sugiani, D., & Nafiqoh, N. (2023). Streptococcosis in Nile tilapia (Oreochromis niloticus) in Indonesian freshwater aquaculture. Omni-Akuatika, 19(1), 1–14. https://doi.org/10.20884/1.oa.2023.19.1.1005

Távara, C. P., Serrano-Martínez, E., Tafalla, C., Burga, C. C., & Llanco, L. A. (2019). Identificación molecular de *Flavobacterium psychrophilum* y caracterización de las alteraciones cutáneas en la trucha arcoíris (*Oncorhynchus mykiss*) procedente de Puno, Perú. Revista de Investigaciones Veterinarias del Perú, 30(4), 1762–1769. http://www.scielo.org.pe/scielo.php?pid=S1609-91172019000400039&script=sci_arttext&tlng=pt

Toro Montenegro, D. (2020). Identificación de genes asociados a la virulencia de *Aeromonas salmonicida* aisladas de truchas arcoíris (*Oncorhynchus mykiss*) procedentes de piscigranjas del Perú (Tesis de maestría). Universidad Peruana Cayetano Heredia. https://hdl.handle.net/20.500.12866/8209

Tran, T. H., Nguyen, V. T. H., Bui, H. C. N., Tran, Y. B. T., Tran, H. T. T., Le, T. T. T., Vu, H. T. T., & Ngo, T. P. H. (2022). Tilapia lake virus (TiLV) from Viet Nam is genetically distantly related to TiLV strains from other countries. Journal of Fish Diseases, 45(9), 1389–1401. https://doi.org/10.1111/jfd.13669

Trung, N. B., Dung, T. T., & Thi, Q. V. C. (2024). Investigation of streptococcosis (*Streptococcus iniae*) as a cause of popeye and hemorrhagic disease in tilapia (*Oreochromis niloticus*) in the Mekong Delta, Viet Nam. Biodiversitas, 25(9), 3032– 3040. https://doi.org/10.13057/biodiv/d250924

USFWS – AFS Fish Health Section. (2014). Columnaris disease. En FHS Blue Book: Suggested procedures for the detection and identification of certain finfish and shellfish pathogens (Chapter 1.2.3). American Fisheries Society.

Verma, V., Prasad, Y., & Singh, B. R. (2011). Effect of pH and salinity on pathogenicity of *Flavobacterium columnare* and Myxobacterium sp. in Indian cat fish, *Clarias batrachus* (Linn.) and *Heteropneustes fossilis* (Bloch.). Journal of Environmental Biology, 32(5), 573.

Wade, J. (2019). Characterization of *Yersinia ruckeri* and enteric redmouth disease (ERM) to inform pathogen transfer risk assessments in British Columbia (DFO Canadian Science Advisory Secretariat Research Document 2019/022). Fisheries and Oceans Canada. https://waves-vagues.dfo-mpo.gc.ca/library- bibliotheque/40853032.pdf

Wallace, I. S., Gregory, A., Murray, A. G., Munro, E. S., & Raynard, R. S. (2008). An analysis of levels of infectious pancreatic necrosis virus in Atlantic salmon, Salmo salar L., broodstock in Scotland between 1990 and 2002. Journal of Fish Diseases, 31(3), 177–186.

Watson, T. R., Bruce, T. J., Ma, J., & Cain, K. D. (2023). Comparison of injection and immersion challenges of *Renibacterium salmoninarum* strains in Rainbow Trout. Journal of Aquatic Animal Health, 35(1), 34–40. https://doi.org/10.1002/aah.10175

Welch, T. J., & Good, C. M. (2013). Mortality associated with Weissellosis (*Weissella* sp.) in USA farmed rainbow trout: Potential for control by vaccination. Aquaculture, 388–391, 122–127. https://doi.org/10.1016/j.aquaculture.2013.01.021

Wise, D. J., Schwedler, T. E., & Terhune, J. S. (1997). Uptake and clearance of *Edwardsiella ictaluri* in the peripheral blood of channel catfish *Ictalurus punctatus* fingerlings during immersion challenge. Journal of the World Aquaculture Society, 28(1), 45-51. https://doi.org/10.1111/j.1749-7345.1997.tb00960.x

Woo, P. T. K., & Bruno, D. W. (Eds.). (2011). Fish diseases and disorders: Vol. 3. Viral, bacterial and fungal infections (2nd ed.). CABI.

World Organisation for Animal Health (OIE). (2021). OIE Aquatic Animal Health Strategy 2021–2025. https://www.woah.org/app/uploads/2021/05/en-oie-aahs.pdf

World Organisation for Animal Health (WOAH). (2023a). México: Tilapia lake virus (TiLV) – infection with tilapia lake virus. WAHIS event report. https://wahis.woah.org/#/event-management

World Organisation for Animal Health (WOAH). (2023b). Philippines: Tilapia lake virus (TiLV) – infection with tilapia lake virus. WAHIS event report. https://wahis.woah.org/#/event-management

World Organisation for Animal Health (WOAH). (2023c). Singapore: Tilapia lake virus (TiLV) – infection with tilapia lake virus. WAHIS event report. https://wahis.woah.org/#/event-management

Yamkasem, J., Tattiyapong, P., Gorgoglione, B., & Surachetpong, W. (2021). Uncovering the first occurrence of tilapia parvovirus in Thailand in tilapia during co-infection with tilapia tilapinevirus. Transboundary and Emerging Diseases, 68(6), 3136–3144. https://doi.org/10.1111/tbed.14143

Yardimci, B., Didinen, B. I., Onuk, E. E., Metin, S., Ciftci, A., Kubilay, A., Pekmezci, G. Z., & Eralp, H. (2015). Immunohistochemical evaluation of experimental Vagococcus salmoninarum infection in rainbow trout

(Oncorhynchus mykiss, Walbaum 1792). Journal of Fish Diseases, 39(5), 547–553. https://doi.org/10.1111/jfd.12386

Zheng, D., Mai, K., Liu, S., Cao, L., Liufu, Z., Xu, W., & Zhang, W. (2004). Effect of temperature and salinity on virulence of *Edwardsiella tarda* to Japanese flounder, *Paralichthys olivaceus* (Temminck et Schlegel). Aquaculture Research, 35(5), 494-500. https://doi.org/10.1111/j.1365-2109.2004.01044.x

Zhu, L., Wang, X., Wang, K., Yang, Q., He, J., Qin, Z., Geng, Y., Ouyang, P., & Huang, X. (2017). Outbreak of infectious pancreatic necrosis virus (IPNV) in farmed rainbow trout in China. Acta Tropica, 170, 63–69. https://doi.org/10.1016/j.actatropica.2017.02.025

Annex 1. Overview of Disease Notification Systems Across APEC Economies

APEC economies have established a wide range of disease notification systems for aquatic animal health. These systems reflect differences in production methods, institutional frameworks, regulatory maturity and risk profiles. Despite this diversity, several common structural elements can be identified across economies. However, there are also important variations and capacity gaps that directly affect the early detection and timely response to aquatic animal diseases.

Across most APEC economies, disease notification systems are anchored in a competent domestic authority responsible for aquatic animal health. This authority is usually located within a ministry or agency that oversees fisheries, aquaculture, agriculture or food safety. These authorities usually base their lists of notifiable diseases on the WOAH Aquatic Animal Health Code, and some economies also include additional diseases of economy or regional importance.

The next table shows the types of notifiable diseases in each APEC economy.

APEC ECONOMY	COMPETENT AUTHORITY FOR AQUATIC ANIMAL HEALTH	TYPE OF LIST / INSTRUMENT	LINK
Australia	Department of Agriculture, Fisheries and Forestry (DAFF)	Domestic list of reportable aquatic animal diseases	https://www.agriculture.gov.au https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/animal-plant/aquatic/field-guide/4th-edition/amphibians/aquatic-diseases.pdf

Brunei Darussalam	Department of Fisheries, Ministry of Primary Resources and Tourism	Domestic aquatic animal pathogen list	https://www.fisheries.gov.bn/Theme/Home.aspx
Canada	Canadian Food Inspection Agency (CFIA)	Reportable Aquatic Animal Diseases	https://inspection.canada.ca https://inspection.canada.ca/en/animal-health/aquatic-animals/diseases/reportable-diseases
Chile	Servicio Nacional de Pesca y Acuicultura (SERNAPESCA)	High-risk aquatic animal diseases (mandatory notification)	https://www.sernapesca.cl https://www.sernapesca.cl/app/uploads/2025/01/ResEx_2858-2024.pdf
China	Ministry of Agriculture and Rural Affairs (MARA)	Domestic aquatic animal disease surveillance list	https://www.moa.gov.cn https://www.moa.gov.cn/govpublic/
Hong Kong, China	Agriculture, Fisheries and Conservation Department (AFCD)	Quarterly Aquatic Animal Disease Reports	https://www.afcd.gov.hk
Indonesia	Ministry of Marine Affairs and Fisheries (MMAF)	Domestic aquatic animal pathogen list (WOAH-based)	https://jdih.kkp.go.id

Japan	Ministry of Agriculture, Forestry and Fisheries (MAFF)	Target diseases of aquatic animals	https://www.maff.go.jp https://www.maff.go.jp/aqs/english/animal/pdf/finfish_diseases.pdf
Korea	National Fishery Products Quality Management Service (NFQS)	Listed diseases of aquatic organisms for quarantine	https://www.nfqs.go.kr https://www.nfqs.go.kr/hpmg/quar/actionEng_sub002.do?utm
Malaysia	Department of Fisheries Malaysia (DOF)	Domestic Fish Health Strategy (WOAH-based)	https://www.dof.gov.my https://www.researchgate.net/publication/336825797_National_Fish_Health_Strategy_Malaysia_2018_-_2022
Mexico	Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria (SENASICA)	Notifiable diseases (terrestrial and aquatic)	https://www.gob.mx/senasica https://dof.gob.mx/nota_detalle.php?codigo=5545304&fecha=29/11/2018#gsc.tab=0
New Zealand	Ministry for Primary Industries (MPI)	Biosecurity Notifiable Organisms Order	https://www.mpi.govt.nz https://www.mpi.govt.nz/dmsdocument/6403-Biosecurity-Notifiable-Organisms-Order-2016
Papua New Guinea	National Fisheries Authority (NFA)	No formal aquatic disease notification list identified	-

Peru	Autoridad Nacional de Sanidad e Inocuidad en Pesca y Acuicultura (SANIPES)	List of infectious diseases of hydrobiological resources	https://www.gob.pe/sanipes https://www.gob.pe/institucion/sanipes/normas-legales/7576507-138-2025-sanipes-pe
the Philippines	Bureau of Fisheries and Aquatic Resources (BFAR)	Domestic aquatic animal disease list (WOAH-based)	https://www.bfar.da.gov.ph https://elibrary.judiciary.gov.ph/thebookshelf/showdocs/10/49962
The Russian Federation	Federal Service for Veterinary and Phytosanitary Surveillance (Rosselkhoznadz o r)	Notifiable animal diseases list (WOAH-based)	https://fsvps.gov.ru
Singapore	Animal & Veterinary Service (AVS)	Notifiable diseases based on WOAH aquatic list	https://www.nparks.gov.sg https://isomer-user-content.by.gov.sg/30/10c9acae-dacf-4955-b137-bbc625d4de67/Guidelines %20for%20reporting%20ND_2019%20Edition%20F inal1updatedApr2020.pdf
Chinese Taipei	Bureau of Animal and Plant Health Inspection and Quarantine (APHIA)	Aquatic animal quarantine disease list	https://www.aphia.gov.tw https://www.aphia.gov.tw/ws.php?id=9578

Thailand	Department of Fisheries (DOF Thailand)	Domestic aquatic animal disease list (WOAH-based)	https://www.fisheries.go.th https://www.angrin.tlri.gov.tw/English/2011Th/2011Th_ch3.pdf
The United States	US Department of Agriculture – Animal and Plant Health Inspection Service (USDA-APHIS)	Domestic List of Reportable Animal Diseases (includes aquatic)	https://www.aphis.usda.gov https://www.aphis.usda.gov/sites/default/files/nlrad-nahrs-disease-list.pdf
Viet Nam	Department of Animal Health (DAH), Ministry of Agriculture and Rural Development	Notifiable aquatic animal diseases list	https://www.dah.gov.vn https://www.digicomply.com/food-regulatory-bodies-standards-and-authorities/department-of-animal-health-dah-und

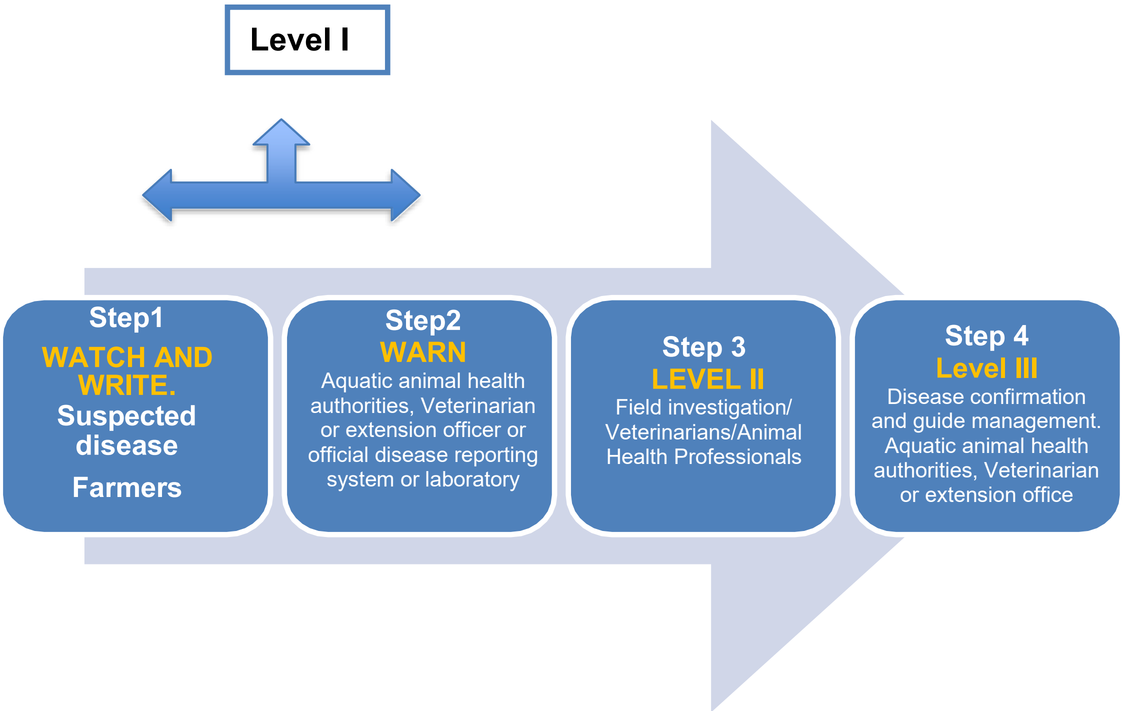
Analysis of institutional information suggests that several APEC economies do not maintain a publicly available, consolidated domestic list of notifiable aquatic animal diseases. In these cases, notification requirements are embedded within broader legislation, technical manuals or inspection-based systems. This limits transparency, producer awareness and regional comparability.

APEC economies use and promote international standards, especially the WOAH Aquatic Animal Health Code (formerly *OIE Aquatic Animal Health Code*) as the primary reference for defining and managing diseases of importance to trade and aquatic animal health

Annex 2. Disease Notification Procedures in APEC Economies.

Notification system Level I focused on farmers.

Figure N° 1
Notification System Step by Step



2.- Main actors participating in notification systems level I across APEC economies.

Aquaculture Producers/Farmers: Fish farmers, hatchery operators

ROLE:

- First to observe abnormal behaviour conduct or mortality, clinical signs or production anomalies
- Mandatory reporters in most APEC economies
- Provide samples and farm-level information
- Increasing use of digital tools, apps, SMS platforms (e.g. Indonesia; Chinese Taipei; and Viet Nam)

Competent Authority (Domestic Level): Veterinary Authority, Fisheries Authority, Aquatic Animal Health Authority

ROLE:

- Receive, validate, and officially register disease reports
- Responsible for international reporting (WOAH / regional)
- Coordinates response and control measures

Regional & Local Government Authorities: Fisheries inspectors, extension officers, regional services

ROLE:

- Forward information to economy level
- Key in community-based surveillance networks
- Observe field conditions
- Support awareness and compliance

Research Institutions & Academia

ROLE:

- Detect emerging diseases through research and surveillance projects
- Share findings with authorities
- Support risk analysis and preparedness

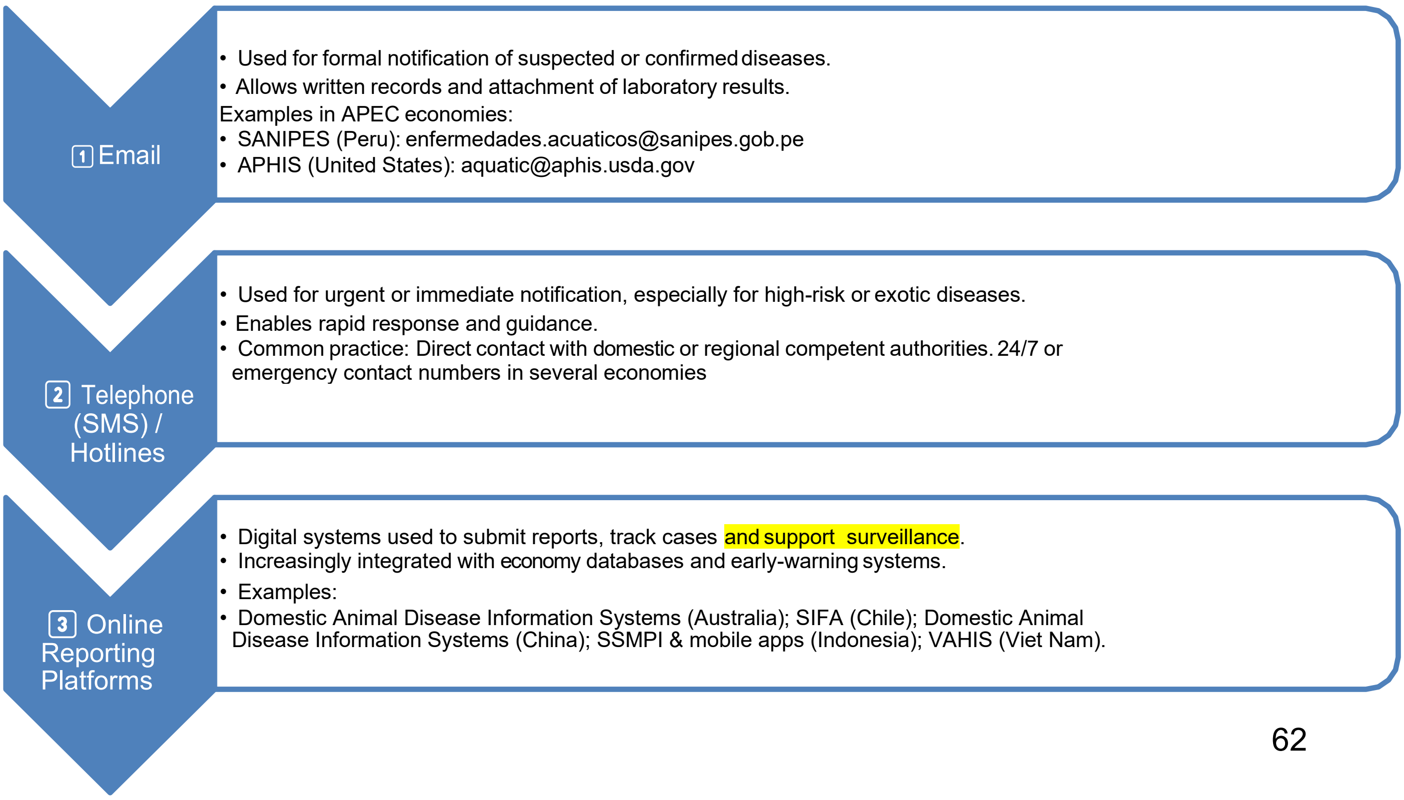
Regional & International Organizations (Complementary): WOAH, FAO, NACA, APEC. Enable regional early warning and cooperation

Figure N°2
Actors in the Aquatic Animal Disease Reporting System, level I (APEC).

3.- Aquatic Animal disease Report system in APEC economies

APEC economies use a variety of channels for notification procedures.

Figure N°9
Official Disease Reporting Channels in APEC Economies

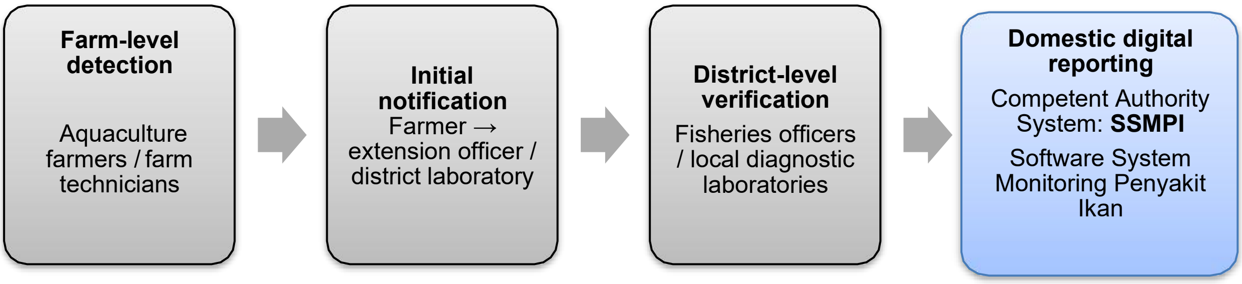


Economies authority validates information, initiates field investigation and laboratory confirmation.

4.- Good practices in notification system at APEC economies

BOX 1 Indonesia – Domestic Aquatic Animal Disease Notification System

Indonesia's notification system combines community-based reporting, digital surveillance (SSMPI) and mobile applications (SiCekatan) to strengthen early detection, accelerate response, and improve domestic and regional transparency in aquatic animal health within APEC economies.



BOX 2 Chinese Taipei Treatment & Diagnosis System (TDS)

TDS is an integrated online platform that supports early detection and risk prediction of aquaculture diseases by linking farm-level diagnostic data with meteorological and environmental information.

TDS compiles standardized data from farms—including diagnostic records, farm and pond location, farming practices, and treatment history—and automatically integrates these with seasonal and weather variables such as temperature and rainfall. Through data analytics and trend analysis, the system identifies seasonal disease risk patterns. In tilapia farming, TDS has been used to anticipate increased risk of bacterial diseases, particularly *Streptococcus iniae* and *Streptococcus agalactiae*, which are strongly associated with elevated water temperatures. The system supports risk-based surveillance, early warning, and timely preventive action by farmers, veterinarians, and authorities.

Key findings on APEC disease notification systems

1. High heterogeneity of disease notification systems
2. The disease notification systems of APEC economies are highly heterogeneous, which limits the comparability of disease data and the effectiveness of regional early warning systems.
3. Uneven accessibility and transparency of notification information
4. Access to official disease notification information varies widely across APEC economies. While some economies have comprehensive, user-friendly online platforms dedicated to aquatic animal health, others rely on fragmented legal texts or documents that are difficult to access and not available in widely used languages.
5. Variable clarity on the role of producers and farm-level reporting
6. In more advanced notification systems, producers and aquatic animal health professionals are legally obliged to report suspected diseases. In contrast, less developed frameworks often primarily assign notification responsibilities to competent authorities or official inspections, providing limited clarity at farm level.
7. Strong potential for APEC-led progressive harmonization
8. Despite their differences, APEC economies face common challenges and have the potential to converge around minimum standards, shared definitions and practical tools for disease notification. APEC provides a strategic platform for progressive harmonisation, based on existing best practices, without the need for uniform regulatory models

Annex 3. Fact Sheets Tilapia

Tilapia Lake Virus Infection (TiLV)

1. Disease name and etiological agent

Tilapia syncytial hepatitis also known as Tilapia Lake Virus Infection, is caused by Tilapia Lake Virus (TiLV), a virus of the genus *Tilapinevirus*, family *Amnoonviridae*.

2. Affected hosts/species/life stages

TiLV primarily affects *Oreochromis mossambicus*, *Oreochromis niloticus*, their hybrids, and *Sarotherodon galilaeus*. The disease can affect fish at all life stages, but mortality is highest in individuals weighing 1 to 50 grams (20–90%) (Surachetpong *et al*., 2017), while adult fish show lower mortality (~9.2%) (Fathi *et al*., 2017). In experimental cohabitation models, mortality begins around day 3 post-infection, peaking between days 4 and 12.

3. Geographic distribution

TiLV has been reported in the following APEC economies: Indonesia; Malaysia; Mexico; Peru; the Philippines; Chinese Taipei; Thailand; and the United States. It has also been reported in Bangladesh; Colombia; Ecuador; Egypt; India; Tanzania; and Uganda.

4. Risk factors

Environmental factors

Clinical outbreaks appear more likely during the hot summer months but have been reported within the water temperature range of 22-32°C (Ponsrinivasan *et al*., 2025; WOAH, 2025).

Management practices:

- Deficiencies in biosecurity: including personnel, equipment, and untreated water intake.
- Purchase of fry from unverified hatcheries.
- High stocking density.
- Water exchanges causing abrupt changes in physicochemical parameters.

5. Mode of transmission

Direct horizontal: Contact between infected and healthy fish.
Indirect horizontal: Via contaminated water, equipment, personnel, or mechanical vectors (e.g., birds, tools).

Excretions and secretions**:** Virus is shed through mucus of infected fish (Aich *et al*., 2022).

Vertical: Possible transmission from subclinical carrier broodstock to offspring.

Reservoirs and asymptomatic carriers: Infected fish can carry and spread the virus without showing clinical signs.

6. Other relevant information

- World Organization for Animal Health (WOAH). (2025). *Aquatic Diseases Field Guide* (Android version) [Mobile application]. Google Play. https://play.google.com/store/apps/details?id=com.aquatic_disease_field_guide.app.woah
- https://www.sanipes.gob.pe/archivos/FICHA_TILV.pdf
- https://www.aphis.usda.gov/livestock-poultry-disease/aquaculture/tilapia- lake-virus?
- https://worldfishcenter.org/publication/overview-tilapia-lake-virus-tilv
- https://enaca.org/?id=871&utm

Infectious Spleen and Kidney Necrosis (ISKNV)

1. Disease name and etiological agent

This disease is caused by the pathogen *Megalocytivirus pagrus1*, formerly known as the Infectious Spleen and Kidney Necrosis Virus (ISKNV).

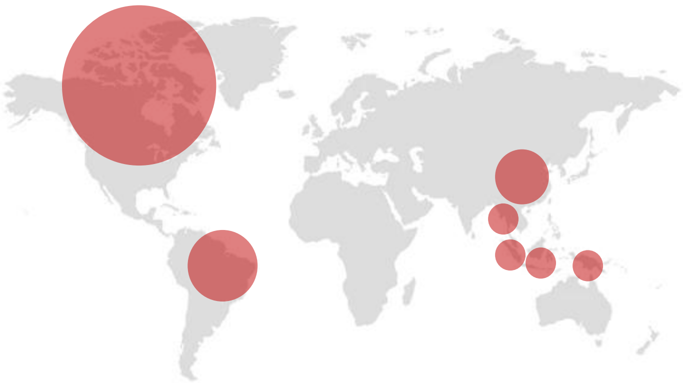
2. Affected hosts/species/life stages

ISKNV affects a broad range of ornamental freshwater and brackish fish species and can also impact farmed species such as tilapia (*Oreochromis* spp.), grouper (*Epinephelus* spp.), and barramundi (*Lates calcarifer*). Mortality rates in affected populations range from 40% to 90%, particularly in juvenile fish.

In experimental cohabitation models, mortality can begin as early as day 3 post-exposure, peaking between days 4 and 12. Under natural conditions, mortalities have been reported 2 to 4 weeks after exposure in areas where the disease is confirmed (Fusianto *et al.*, 2021).

3. Geographic distribution

The disease has been reported in the following APEC economies: Canada; China; Indonesia; Thailand; and the United States. Additional outbreaks have been documented in Brazil.



4. Risk factors Environmental Factors:

Outbreaks of disease occur at water temperatures greater than 20°C, with viral multiplication increasing with water temperatures up to at least 28°C. (WOAH, 2025).

Management practices:

- Deficiencies in biosecurity: including personnel, equipment, and untreated water intake.
- High organic load due to poor feeding practices.
- High stocking density.
- Inadequate water exchange.

5. Mode of transmission

- Direct horizontal: Contact between infected and healthy fish.
- Indirect horizontal: Via contaminated water, equipment, personnel, or mechanical vectors (e.g., birds, tools). Infection via ingestion of excreta or cannibalism is likely
  - Excretions and secretions: Virus is shed through mucus of infected fish.
  - Reservoirs and asymptomatic carriers: Infected fish may harbor and spread the virus without showing clinical signs.
  - There is evidence that some species may be long-term asymptomatic carriers, and the prevalence in infected populations may be high. (WOAH, 2025).

6. Other relevant information

- World Organisation for Animal Health (WOAH). (2025). *Aquatic Diseases Field Guide* (Android version) [Mobile application]. Google Play. https://play.google.com/store/apps/details?id=com.aquatic_disease_field_guide.app.woah
- https://enaca.org/?id=1378&utm
- Ficha ISKNV (Necrosis infecciosa del bazo y riñón) – SANIPES (PDF)
- https://www.agriculture.gov.au/sites/default/files/documents/infection - infectious-spleen-kidney-necrosis-virus-isknv-like-viruses.pdf?

Streptococcosis

1. Disease name and etiological agent

Streptococcal infection is caused by pathogens of the *Streptococcus* genus, with *Streptococcus agalactiae* and *Streptococcus iniae* being the disease most recognized. *S. agalactiae* is of greater significance in aquaculture, with serotypes Ia, Ib, III, and IV reported.

2. Affected hosts/species/life stages

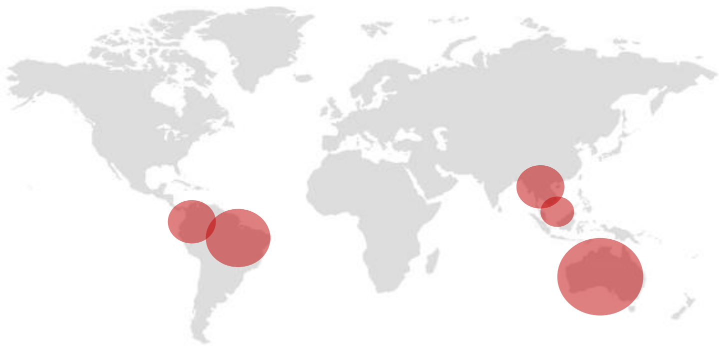
S. agalactiae affects species such as tilapia (*Oreochromis spp.),* catfish (Siluriformes), rainbow trout (*Oncorhynchus mykiss*), crucian carp (*Carassius carassius*), and stingrays (Myliobatoidei). S. iniae affects tilapia (*Oreochromis spp.),* channel catfish (*Ictalurus punctatus*), rainbow trout (*Oncorhynchus mykiss*), European seabass (*Dicentrarchus labrax*), Asian seabass (*Lates calcarifer*), and red drum (*Sciaenops ocellatus*).

Mortality rates range from 30% to 80%, depending on environmental conditions, production stage, and pathogen strain. In severe outbreaks, especially in juveniles, mortality can reach up to 90% (Sule *et al*., 2025).

In experimental cohabitation models, mortality begins around day 3 after infection, peaking between days 4 and 12.

3. Geographic distribution:

Outbreaks of S. agalactiae sequence type ST283 have been reported in Malaysia; Singapore; Thailand; and Viet Nam. Serotype Ia has been documented in Chinese Taipei; it has also been reported in Colombia. Significant outbreaks, without serotype specification, have occurred in China; and Peru. In Australia, serotype Ib has been identified in wild fish and captive stingrays; it has also been detected in tilapia in Brazil.



S. iniae has been reported in both farmed and wild fish in Mexico; and the United States. Its presence has also been confirmed in tilapia farming systems in Indonesia; Malaysia; the Philippines; and Thailand.

4. Risk Factors

Environmental factors

Hypoxic conditions can lead to immunosuppression (Dissolved Oxygen less than 3.5mg/l) and high temperatures may promote persistent infections (≥28°C). (Attia *et al*., 2025, Sule *et al.,* 2025)

Management practices

- Deficiencies in biosecurity: involving personnel, equipment, and untreated water sources.
- High organic load due to poor feeding practices.
- High stocking density.
- Inadequate water exchange.

5. Mode of transmission

- Direct horizontal: through contact between infected and healthy fish.
- Indirect horizontal: via contaminated water, equipment, personnel, or mechanical vectors (e.g., birds, tools).

6. Other relevant information

- https://arxiv.org/abs/2510.27354https://www.sanipes.gob.pe/documentos_sanipes/comunicado/2023/anexo95.pdf

Edwardsiellosis

1. Disease name and etiological agent

Edwardsiellosis is caused by the pathogenic agents *Edwardsiella tarda* and *Edwardsiella ictaluri*, both belonging to the genus *Edwardsiella* and the family *Enterobacteriaceae*.

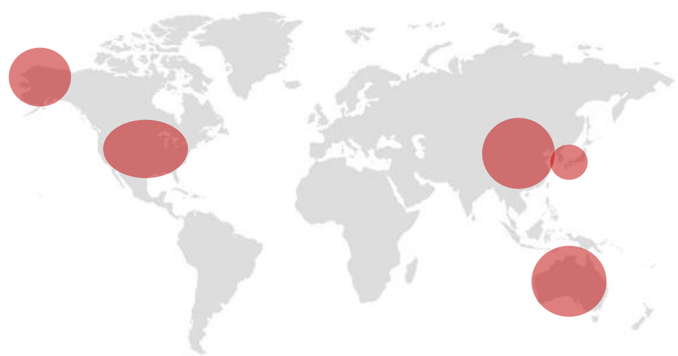
2. Affected hosts/species/life stages

E. ictaluri typically affects ictalurid fish, though it can occasionally infect non-ictalurid species. *E. tarda* has a broader host range, including species such as mullet (*Mugil cephalus*), gilthead seabream (*Evynnis japonicus*), and tilapia (*Oreochromis niloticus*). It can affect fish at all life stages, with a higher susceptibility in juveniles.

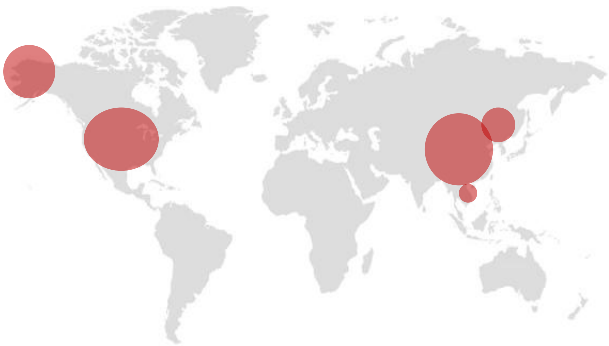
Outbreaks caused by *E. tarda* show variable mortality rates, ranging from 3% to 80%, while *E. ictaluri* infections typically result in 40–50% mortality (Janda *et al*., 2024). In experimental cohabitation models, infection can occur within 24 hours (Wise *et al*., 1997).

3. Geographic distribution:

Edwardsiella tarda has been documented in farmed fish in Australia; China; Japan; Korea; and the United States. Reports include marine species such as turbot in China; marine and ornamental fish in Japan and Korea; and primarily marine environments and aquarium systems in Australia and the United States.



Edwardsiella ictaluri has been reported in China; the United States; and Viet Nam.



4. Risk factors

Environmental factors

High temperatures may favour infections (greater than 25°C). Additionally, temperature gradients greater than 6°C can predispose fish to outbreaks. (Mqolomba *et al*., 1992; Okasha *et al*., 2025; Takeuchi *et al*., 2021; Zheng *et al* 2004).

Management practices:

- Deficiencies in biosecurity: including personnel, equipment, and untreated water intake.
- High organic load due to poor feeding practices.
- High stocking density.
- Inadequate water exchange.

5. Mode of transmission

- Direct horizontal: through contact between infected and healthy fish, especially under high-density conditions.
- Indirect horizontal: via contaminated water, equipment, nets, personnel lacking biosecurity measures, or mechanical vectors like aquatic birds.
- Excretions and secretions: mainly through faeces and bodily fluids of infected fish.

6. Other relevant information

[Edwardsiellosis Fact Sheet (EAZWV Transmissible Disease Handbook)]

Annex 4. Fact Sheets Rainbow Trout

Infectious Hematopoietic Necrosis (IHN)

1. **Disease name and etiological agent**

Infectious Hematopoietic Necrosis (IHN) is caused by the Infectious Hematopoietic Necrosis Virus (IHNV), a virus belonging to the genus *Novirhabdovirus*, family *Rhabdoviridae*.

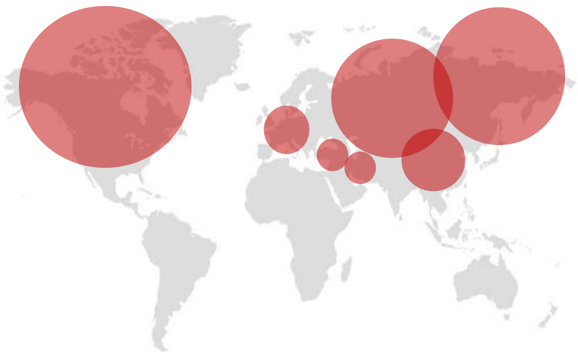
2. **Affected hosts/species/life stages**

IHNV primarily affects fish in the *Salmonidae* family, especially species of *Oncorhynchus* (e.g., *O. mykiss*, *O. tshawytscha*, *O. kisutch*, *O. nerka*) and *Salmo salar*. It has also been experimentally detected in other species such as *Esox lucius* (family *Esocidae*) and *Coregonus* spp. (family *Salmonidae*). The disease shows highest mortality in fish weighing 40–50 grams (Bergmann *et al.*, 2003).

In experimental cohabitation models, mortality appears by day 4 post-infection (Doumayrou *et al*., 2019).

3. **Geographic distribution**

IHNV has been reported in various regions of the Northern Hemisphere and other areas with salmonid farming. The disease is present in the following APEC economies: Canada; China; Japan; Korea; The Russian Federation; Chinese Taipei; and the United States. It has also been reported in France; Germany; Italy; Switzerland; Spain; Turkey; and Iran.



4. Risk factors

Environmental factors:

IHN is a cold-water disease. Clinical signs occur at temperatures between 8°C and 18° C (Marsella *et al*., 2025: WOAH, 2025)

Management practices:

- High fish density, especially in juvenile stages.
- Mixing of batches of different ages or origins without quarantine.
- Use of carrier broodstock or those without prior health screening.
- Stress from handling, transport, grading, or treatments.
- Deficiencies in biosecurity: personnel, equipment, untreated water.
- Lack of surveillance protocols and outbreak response measures.

5. Mode of transmission:

- Direct horizontal: contact between infected and healthy fish.
- Indirect horizontal: via contaminated water, equipment, personnel, or mechanical vectors (e.g., birds, blood feeding parasites, tools).
- Excretions and secretions: virus is shed through urine, mucus, and faeces of infected fish.
- Vertical: possible transmission from subclinical carrier broodstock to offspring through contaminated eggs.
- Reservoirs and asymptomatic carriers: infected fish may harbor and spread the virus without showing clinical signs.

6. Other relevant information

- World Organization for Animal Health (WOAH). (2025). *Aquatic Diseases Field Guide* (Android version) [Mobile application]. Google Play. https://play.google.com/store/apps/details?id=com.aquatic_disease_field_guide.app.woah
- https://www.sernapesca.cl/app/uploads/2025/09/FICHA-TECNICA-DE- ENFERMEDAD-IHN.pdf
- https://www.cfsph.iastate.edu/Factsheets/pdfs/infectious_hematopoietic_necrosis.pdf
- Ficha técnica IHN – SANIPES PDF
- https://inspection.canada.ca/en/animal-health/aquatic animals/diseases/reportable-diseases/ihn/fact-sheet

Infectious Pancreatic Necrosis (IPN)

1. Disease name and etiological agent

Infectious Pancreatic Necrosis (IPN) is an acute viral disease of salmonids caused by IPNV, a double-stranded RNA aquabirnavirus (Mutoloki *et al*., 2016).

2. Affected hosts/species/life stages

IPN primarily affects farmed salmonids such as Atlantic salmon (*Salmo salar*), rainbow trout (*Oncorhynchus mykiss*), and brook trout (*Salvelinus fontinalis*), but it has also been detected in other freshwater and non-salmonid species (Dopazo, 2020; Ruane *et al*., 2009).

The pathogen has also been isolated from various marine species, flatfish, wild fish, and aquatic invertebrates (Dopazo, 2020; Ruane *et al*., 2009).

Severe cases are most commonly seen in fry and juveniles in freshwater and in smolts recently transferred to seawater, although outbreaks have also been reported in post-smolts and adult fish (Roberts & Pearson, 2005).

3. Geographic distribution

IPN is widespread in intensive salmon farming in Canada; Chile; Japan; Korea; and the United States.

4. **Risk factors**

Environmental factors:

Water temperature <15 °C (highest risk at 8–12 °C) (Oidtmann *et al*., 2018).

Management practices:

- Lack of egg disinfection and inadequate broodstock management.
- Shared use of equipment.
- No disinfection of water and effluents.
- Absence of proper vaccination programs.
- High stocking densities.

5. **Mode of transmission**

- Direct horizontal transmission: Occurs through contact between infected and susceptible fish, facilitated by virus shedding in feces and mucus during outbreaks (Dopazo, 2020; Skjesol *et al*., 2011).
- Indirect horizontal transmission: Via exposure to contaminated water, equipment, and structures; the virus retains infectivity for long periods in cold water and organic matter (Oidtmann *et al*., 2018; Dopazo, 2020).
- Vertical transmission: The virus can be present in reproductive fluids, allowing transmission from infected broodstock to offspring through eggs (Smail & Munro, 2008; Wallace *et al*., 2008; Dopazo, 2020).
- Reservoirs and asymptomatic carriers: Surviving fish and wild species may harbor persistent infections and act as environmental reservoirs that reintroduce the virus into farming systems (Ruane *et al*., 2009).

6. **Other relevant information**

- Official reportable disease page with overview and reporting info. CFIA IPN fact sheet (Canada)
- Ficha técnica — Necrosis Pancreática Infecciosa (IPN) (SANIPES PDF) https://www.sanipes.gob.pe/archivos/Ficha_IPN.pdf
- Ficha Técnica de Enfermedad — *Necrosis Hematopoyética Infecciosa (IHN)* (SERNAPESCA / Departamento de Salud Animal, Julio 2025, versión 2) https://www.sernapesca.cl/app/uploads/2025/09/FICHA-TECNICA-DE-ENFERMEDAD-IHN.pdf

Flavobacteriosis (*Flavobacterium psychrophilum*)

1. Disease name and etiological agent

Bacterial Cold-Water Disease (BCWD), also known as peduncle disease or RTFS, is caused by *Flavobacterium psychrophilum*, a yellow-pigmented, psychrophilic, Gram-negative bacillus belonging to the family *Flavobacteriaceae* (Barnes & Brown, 2011; Starliper)

2. Affected hosts/species/life stages

Flavobacterium psychrophilum primarily affects cultured and wild salmonids, with rainbow trout (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), chinook salmon (*O. tshawytscha*), Atlantic salmon (*Salmo salar*), and brown trout (*Salmo trutta*) being the most relevant hosts in aquaculture (Nematollahi *et al*., 2003; Starliper, 2011).

The bacterium has also been isolated in non-salmonid species such as ayu (*Plecoglossus altivelis*), common carp (*Cyprinus carpio*), sturgeons (*Acipenseridae*), eels (*Anguillidae*), and sea lamprey (*Petromyzon marinus*), usually in localized outbreaks or subclinical carriers (Iida & Mizokami, 1996; Lehmann *et al*., 1991).

The disease affects fish of all ages but is most severe in early life stages; eggs and fry can carry the bacterium. RTFS and BCWD clinical signs are primarily observed in fry, while chronic skin lesions and mild septicemia predominate in juveniles and adults with lower mortality (Cipriano & Holt, 2005; Starliper, 2011).

3. Geographical distribution

F. psychrophilum has a nearly global distribution, with reported cases across the Americas, Europe, and Asia.

4. Risk Factors

Environmental factors:

Water temperature: highest risk at 8–15 °C (Secades *et al*., 2001; Smith, 2019).

Management practices

- High stocking densities.
- Delayed removal of mortalities.
- Overfeeding and accumulation of feces.
- Inadequate disinfection of equipment, nets, trays, and water systems.
- Lack of record-keeping and system monitoring.
- Absence of egg disinfection and poor broodstock management.

5. Mode of transmission

- Direct horizontal transmission: Infected fish with ulcers or caudal necrosis release high bacterial loads into the water (Cipriano & Holt, 2005).
- Indirect horizontal transmission: Occurs through exposure to contaminated water, surfaces, and fomites; the pathogen can persist in aquatic sediments (Madetoja *et al*., 2003; Oplinger & Wagner, 2015).
- Vertical transmission: May occur from broodstock to offspring via contaminated eggs, including intraovum infection resistant to disinfection (Brown *et al*., 1997; Cipriano, 2005; Kumagai *et al*., 1998).
- Subclinical carriers: Both broodstock and surviving fish can harbor persistent infections and spread the pathogen without showing clinical signs (Ekman *et al*., 1999).

6. Other relevant information

- Flavobacteriosis (Bacterial Cold Water Disease) – CFIA
- https://inspection.canada.ca/en/animal-health/aquatic-animals/diseases/reportable-diseases/bacterial-cold-water-disease
- Bacterial Cold Water Disease – Fish Health Fact Sheet https://www.fws.gov/media/bacterial-cold-water-disease

Flavobacteriosis (*Flavobacterium columnare*)

1. Name of the disease and etiologic agent

Columnaris disease, also called "saddle" or "cottonmouth", is caused by *Flavobacterium columnare*, an aerobic, slippery Gram-negative bacillus, pigmented yellow by flexirubin and belonging to the family Flavobacteriaceae (Austin & Austin, 2012; Declercq *et al*., 2013; Smith, 2019).

2. Affected hosts/species/life stages

Flavobacterium columnare affects freshwater fish in both cultured and wild populations, with a wide range of susceptible species, including salmonids, cyprinids, catfish, tilapia and ornamental fish (Declercq *et al*., 2013).

In salmon farming, it has been described in rainbow trout (*Oncorhynchus mykiss),* Atlantic salmon *Salmo salar* and brook trout (Salvelinus fontinalis), with relevant mortalities in intensive systems (Woo and Bruno, 2011).

The disease can occur at all stages of life, being more serious in fry, where it usually manifests itself acutely with episodes of high mortality. In juveniles and adults, skin and gill lesions of acute or chronic course predominate (Declercq *et al*., 2013).

3. Geographical distribution

It has a practically worldwide distribution in freshwater ecosystems, with reports in America, Europe and Asia.

4. Risk factors

Environmental factors:

Temperature: highest risk at 20–30 °C. (Declercq *et al*., 2013; Dietrich *et al*., 2011; Verma *et al*., 2021).

Management factors:

- High stocking densities.
- Poor water quality.
- Overfeeding.

- Management procedures can lead to micro-injuries.
- Late withdrawal of mortalities.
- Deficient disinfection of materials and fomites transported by personnel.
- Entry of subclinical carriers.

5. Mode of transmission

- Direct horizontal route: By contact between infected and susceptible fish, facilitated by lesions that release high bacterial loads into the water.
- Indirect horizontal route: Through contaminated water, sediments or surfaces, where the pathogen can persist and be transmitted even without visible diseased fish. (Declercq et al., 2013; USFWS–AFS Fish Health Section, 2014).
- Vertical route: Not confirmed, but the presence of the agent in eggs and hatching water suggests possible early exposure. (Declercq et al., 2013).
- Subclinical carriers: Surviving or wild fish can persistently harbor the bacterium and intermittently release it into the environment. (Austin & Austin, 2012; Declercq et al., 2013).

6. Other relevant information

- Columnaris disease – CFIA
- https://inspection.canada.ca/en/animalhealth/aquaticanimals/diseases/reportable-diseases/columnaris

Renibacteriosis

1. Disease name and etiological agent

Bacterial Kidney Disease (BKD) is a systemic infection caused by the facultatively intracellular Gram-positive bacterium *Renibacterium salmoninarum*, which belongs to the phylum Actinobacteria.

2. Affected hosts/species/life stages

Renibacterium salmoninarum primarily affects fish in the Salmonidae family, including rainbow trout (*Oncorhynchus mykiss*), Atlantic salmon (*Salmo salar*), Pacific salmon (various *Oncorhynchus* species), brown trout (*Salmo trutta*), chum salmon (*Oncorhynchus keta*), and non-salmonids like the cleaner fish *Cyclopterus lumpus* (Florez-Jalixto *et al*., 2021; Kong *et al*., 2024; Gnanagobal *et al*., 2021).

It affects all life stages, with higher mortality in juveniles, while in adults it often causes chronic infections (Fetherman *et al*., 2020). In experimental injection models, mortality starts around day 19; in immersion models, clinical signs may appear up to 28 days post-exposure (Watson *et al*., 2023).

3. Geographic distribution

Outbreaks have been documented in Canada; Chile; Japan; Korea; and the United States.

4. Risk factors

Environmental factors:

Cool water (often 8–15 °C). (Purcell *et al*., 2016; Dietrich *et al*., 2011; Svobodova *et al*., 1993).

Management practices

- High stocking density.
- Lack of egg disinfection and poor broodstock management.
- Use of contaminated water sources.

5. Mode of transmission

- Direct horizontal: Through direct contact or waterborne exposure (Persson, 2022).
- Indirect horizontal: R. salmoninarum is shed via feces and mucus and can survive up to 21 days in feces and sediments (Nielsen et al., 2020).
- Vertical: The bacterium can infect the reproductive organs of chronically infected broodstock, contaminating eggs during formation and spawning (Cook et al., 1999).
- Subclinical carriers: Transmission from subclinical carriers to healthy fish has been reported (Suzuki et al., 2018).

6. Other relevant information

Disease cards / technical resources (NACA Library). https://enaca.org/?id=700