“Sanità e Sicurezza alimentare dell’acquacoltura Italiana”
26 gennaio 2023 - Verona

Nuove Minacce Ambientali per la Troticoltura

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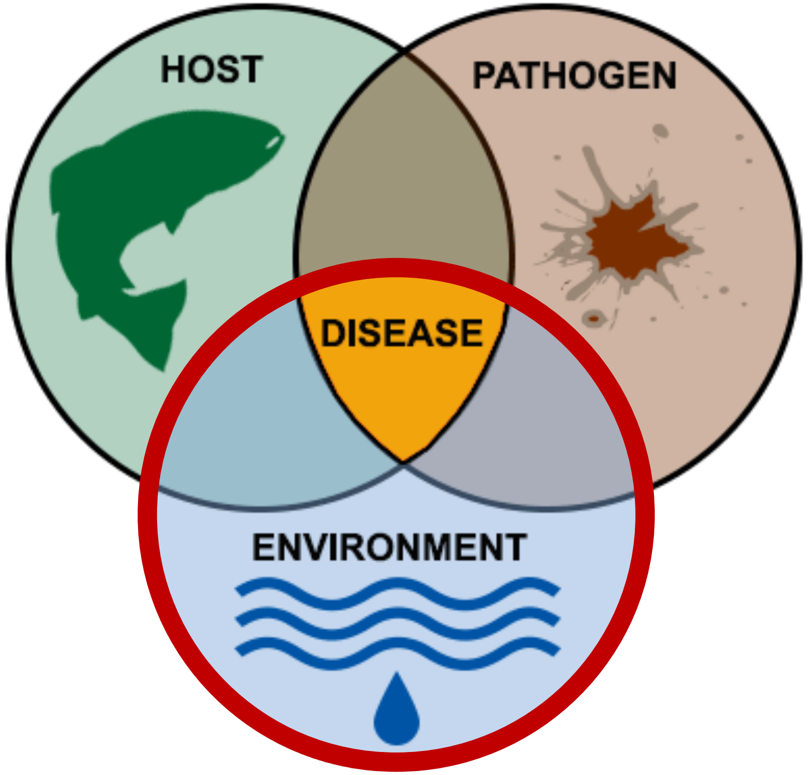
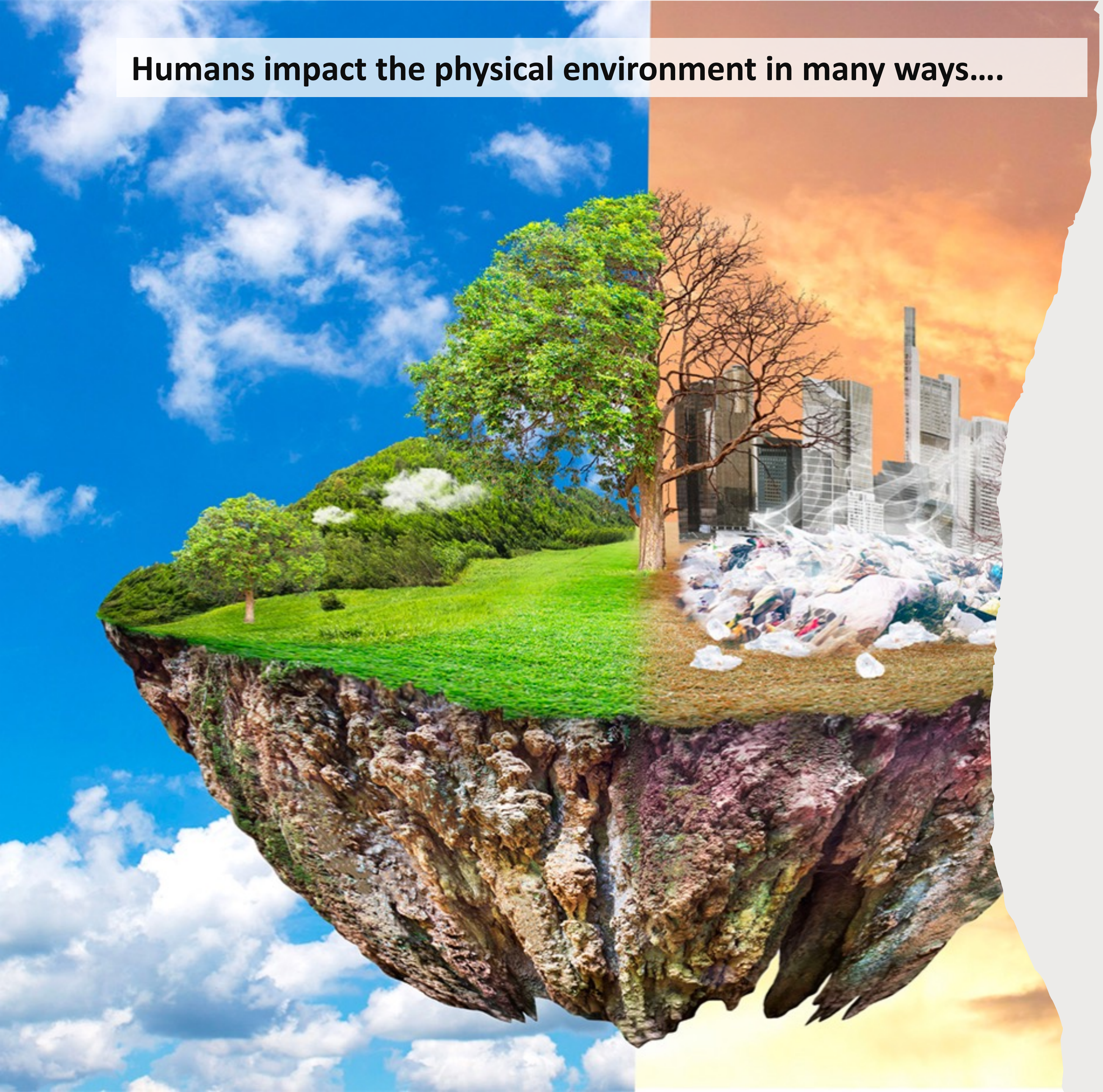
AQUACULTURE AND ENVIRONMENT

AQUACULTURE ⟷ ENVIRONMENT



Conceptually, it is useful to think of fish disease or fish health as a set of interactions among the host, pathogen and environment.



GLOBAL CHANGE

What does the term "global change" mean?

We understand global change to comprise a wide range of biophysical, ecosystem and socio-economic changes that alter the functioning of Earth as a system on a planetary scale (changes in climate, land and ocean productivity, atmospheric and water chemistry, ecosystems). **The result is a change in Earth's ability to support life**.

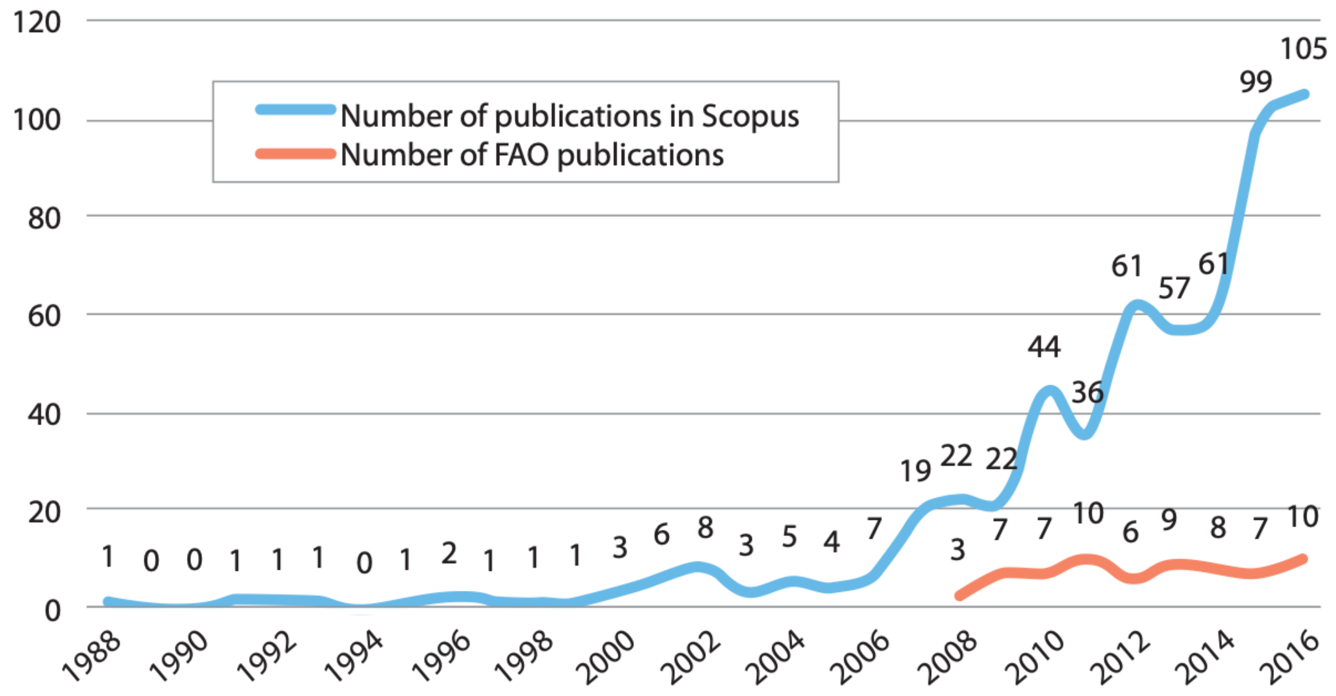
THREATS TO TROUT FARMS

- Climate change
- Water scarcity
- Emerging contaminants
- (Re)emerging diseases

CLIMATE CHANGE AND AQUACULTURE

The first mention of research on climate change and aquaculture in the scientific literature was at the end of the 1980s (Sherwood, 1988) but it took more than 15 years after that for researchers to invest significant effort on the topic.

Numbers of published scientific papers per year dealing with aquaculture and climate change in Scopus and FAO databases, as a proxy of interest in the issue



CLIMATE CHANGE AND AQUACULTURE

- Direct and indirect climate change drivers can be responsible for changes in aquaculture, whether in the short- or long-term.

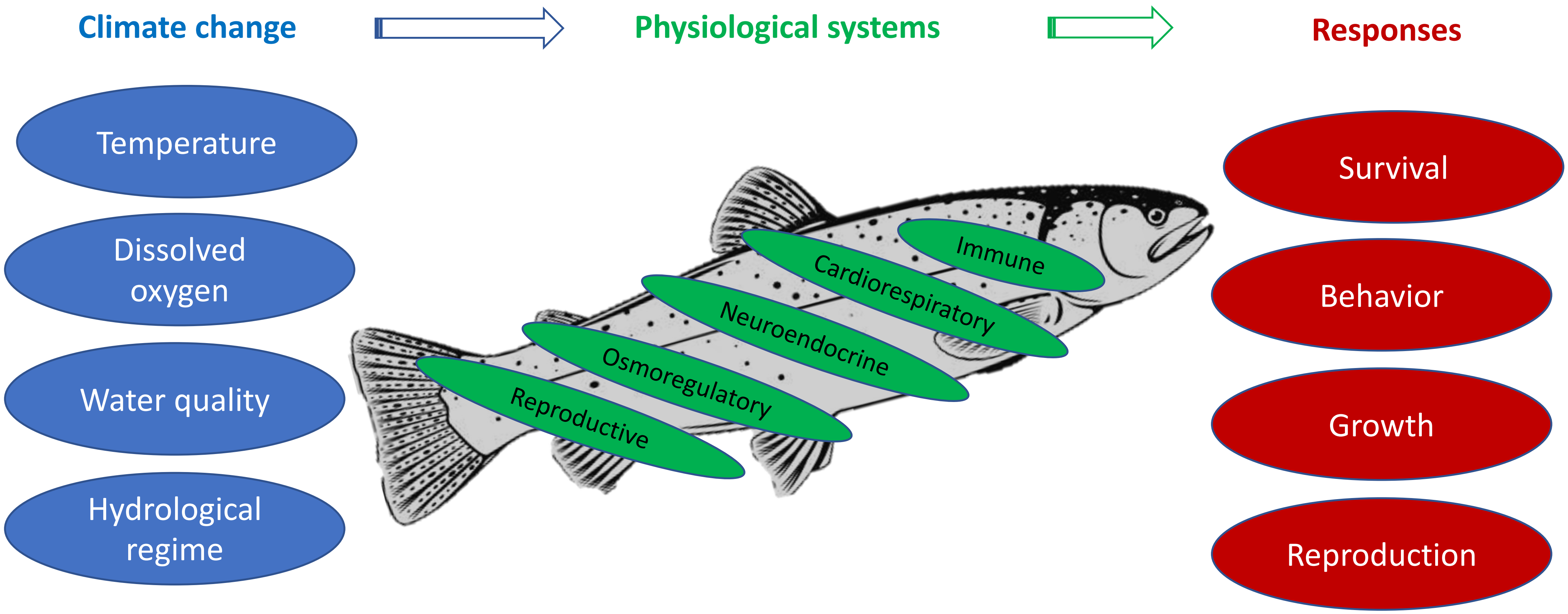
- Short-term impacts include loss of production or infrastructure due to extreme events (i.e., flood, tornadoes), diseases, toxic algae and parasites.

- Long-term examples include limited access to freshwater for farming, limited access to feeds from marine and terrestrial sources, decreased productivity due to suboptimal farming conditions, eutrophication and other perturbations.

CLIMATE CHANGE AND AQUACULTURE: a global overview

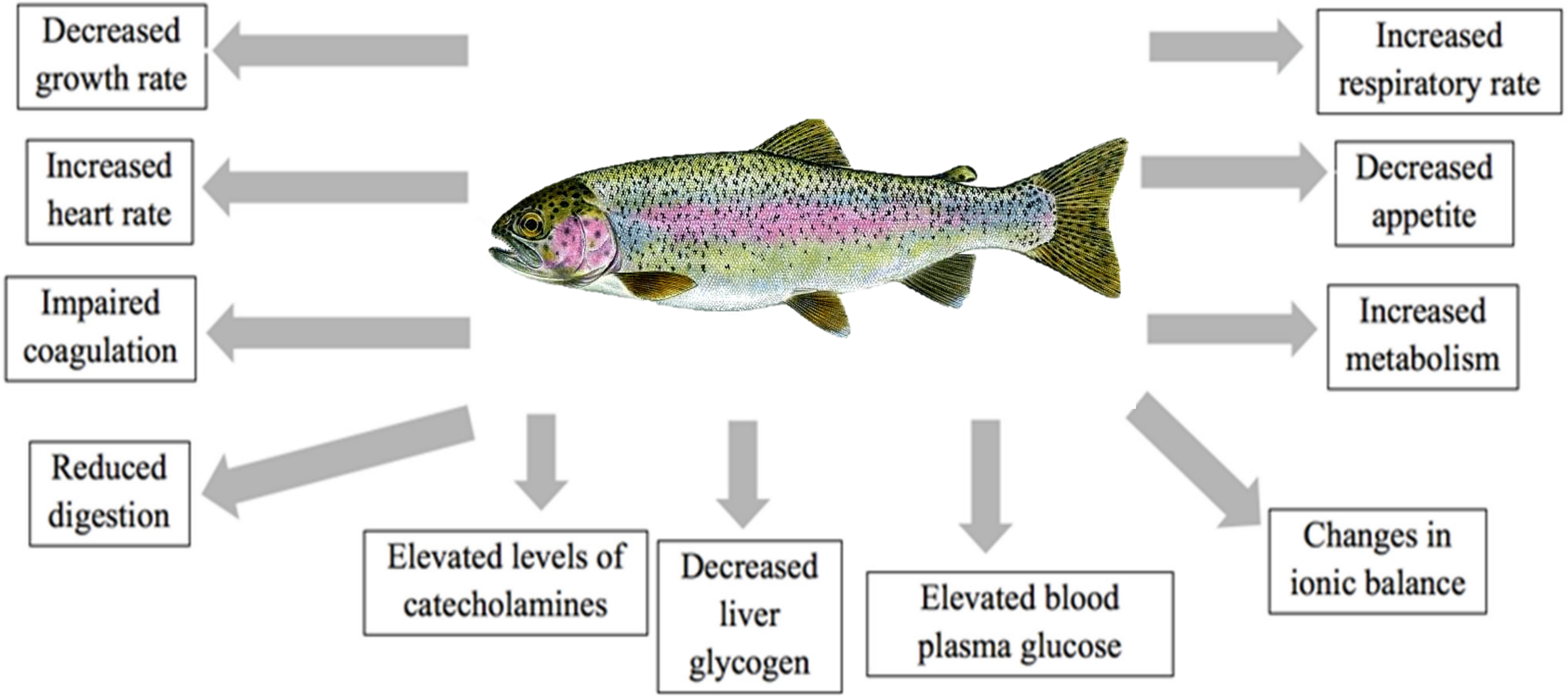
Drivers		**Aquatic organisms**	**People**	**Farming system**
Warming	Potential impacts	• Increased metabolism and growth rate	• Increased production, improved feed conversion and shorter production cycles should translate into a more profitable sector and higher income	• Increased farm production • Improved feed conversion efficiency for species with higher thermal tolerance • Shift to shorter production cycle aquaculture; intensified production
		• Increased plankton respiration and proliferation • Changes in mollusc spatfall • Changes in reproduction and sex ratios • Increased/decreased transmission of some diseases	• Relocation of some farming facilities (e.g. seaweed, finfish, shellfish) to cooler/deeper areas in the sea may create new safety risks • Moving facilities may affect livelihoods and increase production cost	• HABs may force farm movement/closure or installation of depuration facilities • Effects of increased jellyfish blooms on marine farms • Lower feed conversion efficiency for species subjected to increased stress
		• Species with a narrow thermal range may no longer be farmed • Increased sensitivity to other drivers (e.g. acidification, pathogens) • Increased Harmful Algal Blooms (HABs)		
	Adaptation measures	• Farm species and/or strains with higher thermal tolerance • Move farming facilities to cooler/deeper offshore or inland areas	• Adopt guidelines on decent work in aquaculture (e.g. FAO, 2016b)	• Selective breeding for thermal tolerance • Adjustment in farming calendar/practices • Change of farmed species • Climate-smart facilities (e.g. deeper ponds, etc.)

Conceptual model describing the responses of fish physiological systems to climate change



The left column lists abiotic characteristics of freshwater ecosystems that are influenced by climate change, which, in turn, influence five physiological systems within an individual fish. The right column describes how scientists or managers could measure different responses resulting from climate change effects on fish physiology.

Schematic representation of the major climate change stressors in rainbow trout farming



Climate change affects and alters environmental factors influencing the welfare of rainbow trout (*O. mykiss*) and, therefore, problems in the growth rate and welfare of the fish may occur

European Aquaculture: Climate Change Adaptation and Mitigation

Advice to the Aquaculture Advisory Council

Final Report

October 2022

Water scarcity

Water makes life possible since life without water is not sustainable. Water provides many beneficial functions, both for the earth and for humans—that help produce the abundance of life around us every day.

Water covers about 70% of the planet, giving it the unique ability to foster and sustain life. Yet, <2.5% is freshwater, available for consumption, of course after processing.

The three major sources of freshwater are rainwater, surface water and groundwater.

Water scarcity is the deficiency of adequate water resources that can meet the water demands for a particular region.

By one definition, human populations face water scarcity when annual water supplies in a region fall below 1,000 m^3 $person^{-1}$, which currently occur throughout most countries in Northern Africa and the Arabian Peninsula.

Contribution of 'The water we eat!!' to water scarcity

- We «eat» 3496 litres of water every day!!
- 'Eating water' – it might sound strange, but it's the reality. This is the water associated with the production of food we consume daily. In fact the water we essentially need for drinking is only about 0.01% of the water we require to produce our food.
- Most of the world's freshwater goes to agriculture, mainly for the production of crops, livestock and aquatic organisms, such as fish and plants, as well as for the processing and preparation of these foods and products.
- At present agriculture accounts for nearly 70% of all freshwater withdrawn from rivers, lakes, and aquifers globally (FAO, 2011) which is equivalent to 3600 km^3 $year^{-1}$ (Including losses).

Estimated water consumption in inland aquaculture

Aquaculture in inland freshwater contribute maximum to the world aquaculture production (contributed 63% of the world aquaculture production in 2016) and at the outlook, inland freshwater aquaculture seems as a highly water-intensive endeavour, requiring much more water than conventional agriculture, withdrawing on average 16.9 m^3 water for per kg production (FAO, 2017).

	Water use variable	**Water consumption per kg production**	**World total water use in inland aquaculture (in km3/yr)**
A. System associated water consumption			
1.	Evaporation losses	5,200 L (5.2 m^3)	131
2.	Infiltration losses	6,900 L (6.9 m^3)	175
3.	To regulate water exchange	3,100 L (3.1 m^3)	79
B. Feed associated water consumption		1,700 L (1.7 m^3)	44.1
C.	Gross total water consumption (A + B)	16,900 L (16.9 m^3)	429.1
D.	1. Recycled water (Infiltration losses + water exchange losses) (A2 + A3)	10,000 L (10 m^3)	254
E.	2. Net total water consumption (C – D)	6,900 L (6.9 m^3)	175.1

World Bank has estimated that, aquaculture's contribution to world's fish consumption will rise from current 40% to roughly 62% by 2030; and thus consequently water demand for the sector will rise significantly (Hussan et al., 2019).

The potential of rainbow trout farming in aquaponics

- Nowadays, rapidly elevated levels of carbon dioxide (CO_2) have threatened rainbow trout aquaculture and global food security.
- To increase the global aquaculture production, despite climate change, an expansion of sustainable aquaculture systems (e.g., aquaponic systems etc.) is needed in the context of a circular economy.
- Aquaponics, in combination with selective breeding and thermal acclimation, are promising management strategies that may contribute to the development of a new form of rainbow trout farming
- Modern freshwater aquaculture relies mainly on closed aquaculture systems (RAS), which reuse the same volume of water. In these systems, the rate of water reuse ranges between 80 and 99%, therefore reducing water requirements and the environmental impact of aquaculture.
- The unification of closed aquaculture systems (RAS) and hydroponics—known as aquaponics—improves sustainability and ensures food sufficiency, providing various significant economic and social benefits.
- These innovative sustainable aquaculture systems, already implemented, are characterized as integrated multi-trophic aquaculture (IMTA) or polycultures.

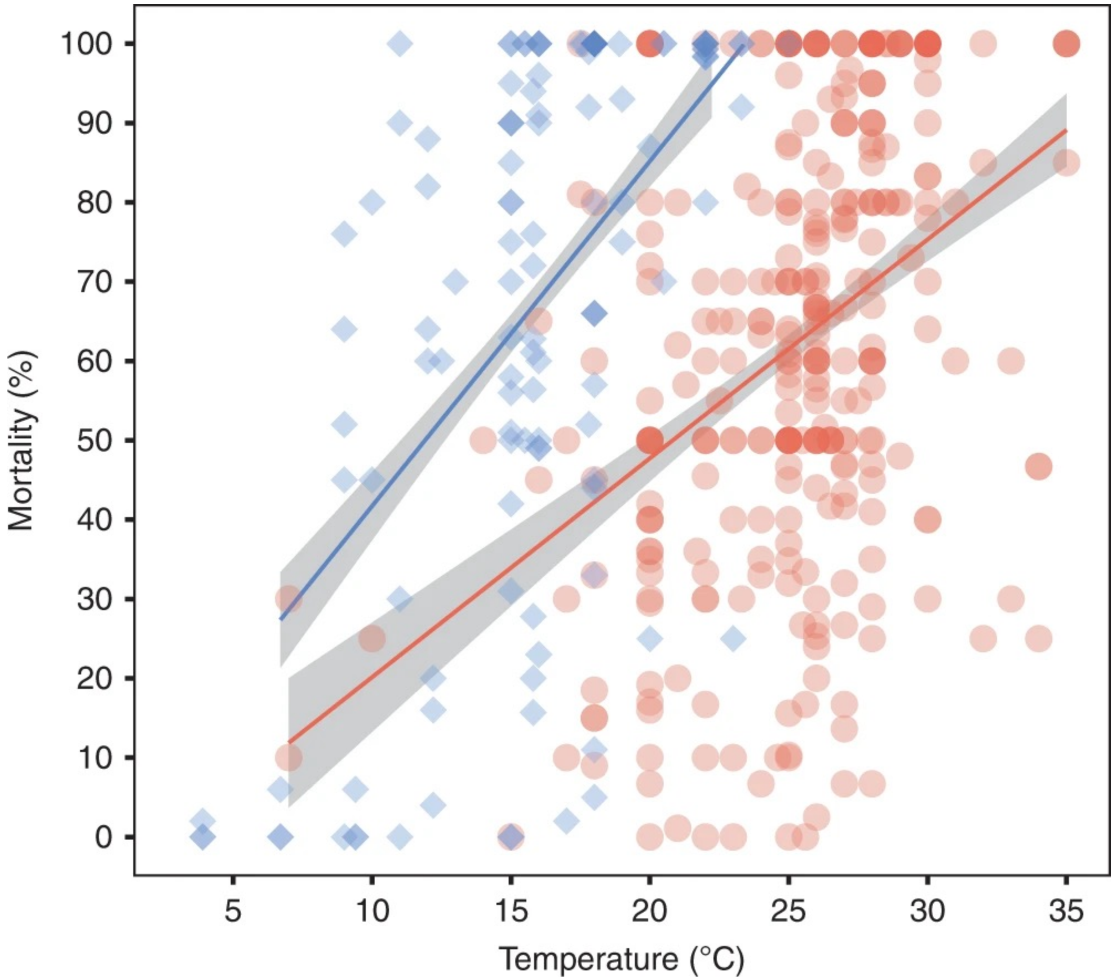
Aquaponics as a promising strategy to mitigate impacts of climate change on rainbow trout culture

However, the rainbow trout has not been commercially reared so far in such systems.

It should be noted that rainbow trout may represent an optimum candidate for an aquaponic system

Experimental research of rainbow trout aquaculture in an aquaponic system in Greece (Vasdravanidis et al., 2022).

The increase in the temperature of the water can cause thermal stress on the fish, burdening their immune systems and leading to greater susceptibility to diseases



Bacterial pathogens: *Aeromonas* spp., *F. columnare*, *Lactococcus* spp., *Streptococcus* spp., *Vibrio* spp., and *Yersinia* spp. Red indicates tropical and subtropical host species (n = 329), blue indicates temperate host species (n = 129). Dots represent the raw data and the lines the linear mixed model predictions with SE.

Models predicted that a temperature increase of 1 °C in warm-water infected with bacteria could lead to increases of mortality of 3.87–6.00% respectively.

Reverter et al., 2020

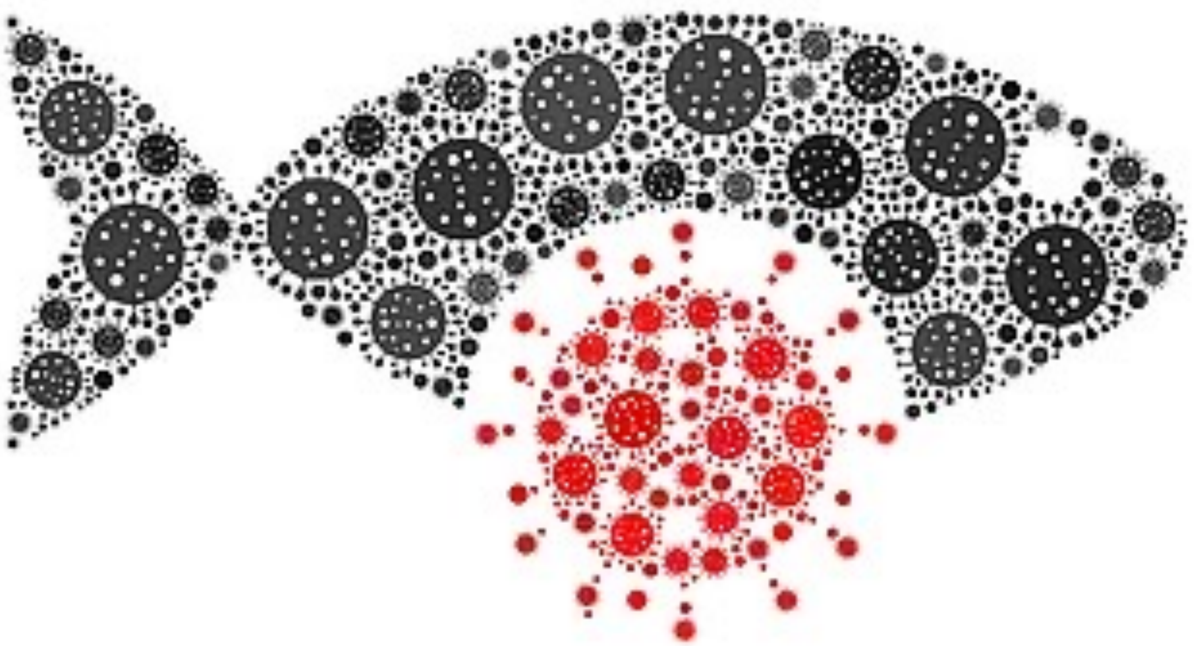
(Re)Emerging Diseases

Enteric red mouth disease

Columnaris Disease

Proliferative kidney disease

Fish Streptococcosis



Fish Streptococcosis

Warmwater Streptococcosis

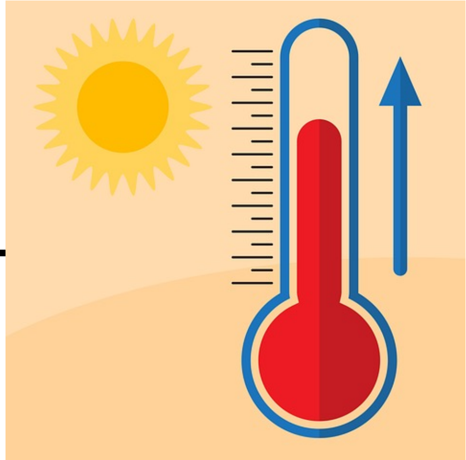
Lactococcus garvieae/L. petauri

Streptococcus iniae

Streptococcus agalactiae

Streptococcus parauberis

15° C



Coldwater Streptococcosis

Vagococcus salmoninarum

Lactococcus piscium

Carnobacterium maltaromaticum

Emerging contaminants

Water contamination is a serious problem, with 22% of surface water bodies and 28% of groundwater in the European Union being significantly affected by diffuse pollution.

- Contaminants of emerging concern (CECs) are typically divided into chemicals, as they are properly called, and biological CECs, such as pathogens.

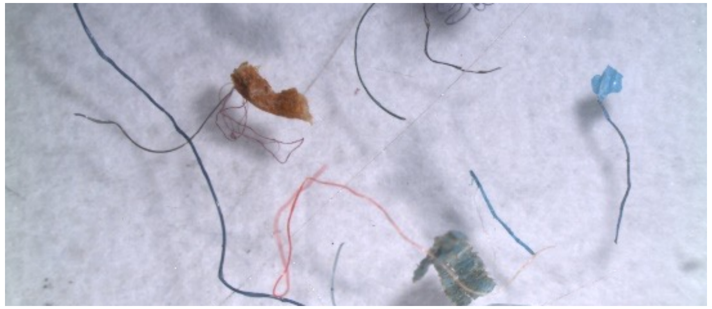
- CECs comprise a vast array of contaminants that have only recently appeared in water, or that are of recent concern because they have been detected at concentrations significantly higher than expected, and/or their risk to human and environmental health may not be fully understood

- CECs span natural and artificial chemical substances and their by-products, comprising pharmaceuticals, personal care products (PPCPs), flame retardants (FRs), pesticides, nanoparticles, microplastics and their transformation products, but also antibiotic resistant bacteria (ARB), antibiotic resistant genes (ARG)

TYPES OF MICROPLASTICS | Overview

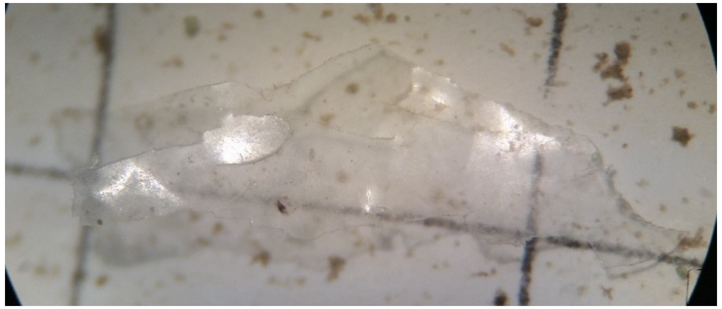
MICROPLASTICS ARE PIECES OF PLASTIC 5 MILLIMETRES OR SMALLER.

Fibres



Pellets

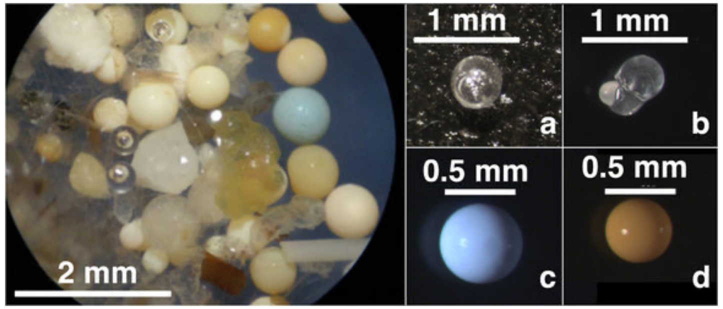
Films



Fragments

Foam

Microbeads



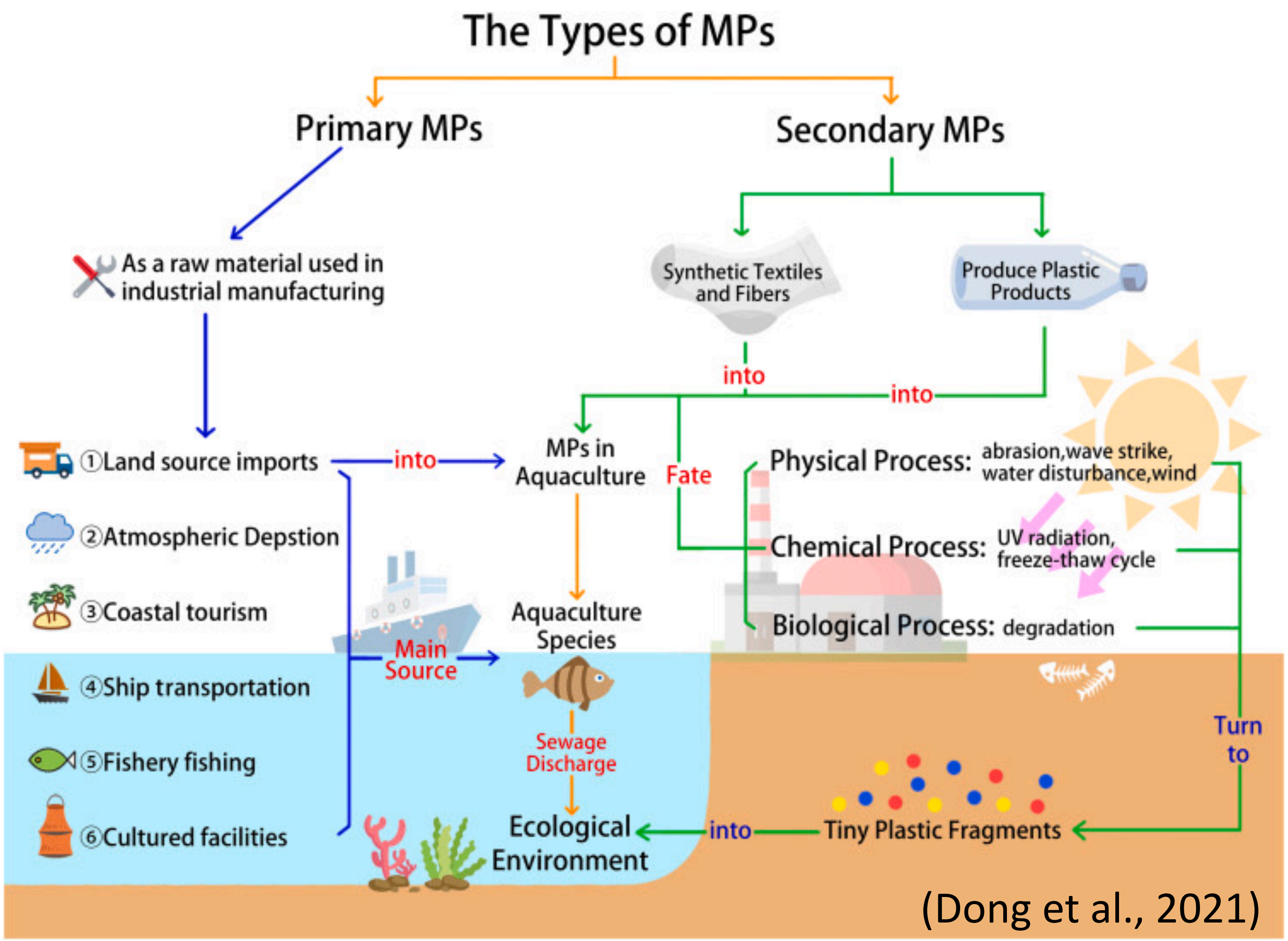
PRIMARY MICROPLASTICS

Those which enter the aquatic environment in their « micro » size

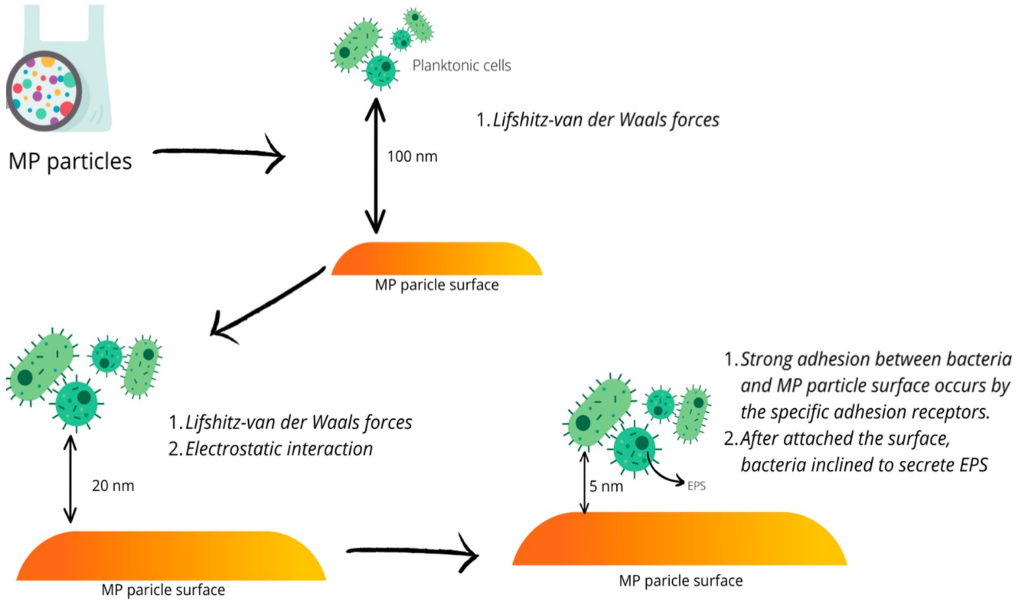
SECONDARY MICROPLASTICS

Resulting from the breakdown of larger plastics in the marine environment

The sources, distributions, and behavior characteristics of MPs in the aquaculture



(Dong et al., 2021)



Cholewinska et al., 2022

The sources, distributions, and behavior characteristics of MPs in the aquaculture

Table 1
The concentrations and characteristics of microplastics in the aquaculture systems.

Site	Source	Abundance	Size	Shape	Composition	Color	Reference
Xiangshan Bay, China	seawater	8.9 ± 4.7 items/m^3	Ave: 1.54 ± 1.53 mm.	fiber, film, fragment, foam	PE, PP, PS, PA, PET, cellulose	N/A	Chen et al. (2018)
	sediment	17.39 ± 21.53 items/kg	Ave: 1.33 ± 1.69 mm	fiber, film, fragment, foam	PE, PP, PET, Rubber, cellulose		
Xiangshan Bay, China	sediment	33-113 items/kg, Ave: 74 items/kg	345–4998 μm, Ave: 1830 μm	fiber, film, fragment	Cellulose, PA, AN, PP, PET	N/A	Wu et al. (2020)
Fish farms in Mediterranean, Spain	sediment	0 to 213 items	0.128–5 mm	fiber, fragment, pellet	PE, PP, PA, cellulose	black, transparent, blue, yellow, red	Krüger et al. (2020)
Fish ponds in Changzhou, China	freshwater	13 to 27 items/L	<0.1–5 mm	fiber, film, fragment, pellet	PE, PP, PS, PA, PET	transparent, white, green, yellow, gray	Wang et al. (2020)
Maowei Sea, China	seawater	1.2–10.1 items/L, Ave: 4.5 ± 0.1 items/L	<0.25–5 mm	fiber, flake, foam, fragment	PES, PP, PE, PA, PS, POM, PU, PBT	white, yellow, blue, green, red, black	Zhu et al. (2019)
Fish ponds in Carpathian basin, Europe	freshwater	3.52–32.05 items/m^3, Ave: 13.79 ± 9.26 items/m^3	N/A	N/A	PE, PP, PS, PTFE, PAC, PES	N/A	Bordós et al. (2019)
	sediment	0.46 to 1.62 items/kg, Ave: 0.81 ± 0.37 items/kg					
Fish ponds in Guangzhou, China	freshwater	42.1 items/L	<0.1–3 mm	fiber, film, granule, fragment, pellet	PP, PE	blue, purple, transparent, white, black, green, yellow, red	Ma et al. (2020)
Rice-fish co-culture system in Shanghai, China	freshwater	0.4 ± 0.1 items/L	<1–5 mm	fiber, film, granule, fragment	PE, PVC, PP	black, transparent, blue, white	Lv et al. (2019)
	sediment	10.3 ± 2.2 items/kg					
Mussels farming in Jurujuba Cove	seawater	16.4/m^3	<1–5 mm, dominant: < 1 mm	fragment, fiber, sheet, pellet	PE, PP	blue, green, red, yellow, orange, black	Castro et al. (2016)
Eel culture stations, Shanghai	water	1.0 ± 0.4 items/L	<0.1–5 mm	film, fiber, fragment, granule	PE, PP, EA	yellow, green, white, black, blue, translucent	Lv et al. (2020)
	soil	27.1 ± 7.0 items/kg					
Milkfish ponds in Muara Kamal	water	103.8 ± 20.7 items/L	N/A	fiber, film, fragment, granule	N/A	N/A	Priscilla and Patria. (2019)
	sediments	111680 ± 13204 items/kg					
Milkfish ponds in Marunda	water	90.7 ± 17.4 items/L					
	sediments	82480 ± 11226 items/kg					
Shrimp-culturing farm in Longjiao Bay, China	seawater	250-5150 items/m^3, mean: 1594 items/m^3	0.3–5 mm (92.03%) <0.3 mm (7.97%)	fiber, fragment, foam, film, granule	PE, PET, PS, PP, PC, PA, PAA	granule, fibers, white, yellow, black	Chen et al. (2020a)
Artificial reefs in Ma'an Archipelago, China	seawater	0.2 ± 0.1–0.6 ± 0.2 items/L	1–5 mm	fibers, fragments, films	PA, PE, PP, PS, cellulose, cellophane	blue, transparent, black, red, green, yellow, white	Zhang et al. (2020b)
	sediment	30.0 ± 0.0–80.0 ± 14.1 items/kg	0.05–1 mm (dominant)				
Eight sea cucumber farms along the Bohai Sea and the Yellow Sea in China	sediment	20 - 1040 items/kg	<1 mm (82%) 1–5 mm (18%)	fibers, fragments, films	cellophane, polyester, PET, PE, PP, PA, PVA, PAN	blue, transparent, black, red, purple, brown	Mohsen et al. (2019)

(Chen et al., 2021)

ELSEVIER
Aquaculture
Volume 512, 15 October 2019, 734322

Comparison of microplastic contamination in fish and bivalves from two major cities in Fujian province, China and the implications for human health

Chao Fang [a], Ronghui Zheng [a], Hongzhe Chen [b], Fukun Hong [a], Longshan Lin [a], Hui Lin [b], Huige Guo [b], Christyn Bailey [c, d], Helmut Segner [c], Jingli Mu [e], Jun Bo [a]

ELSEVIER
Science of The Total Environment
Volume 708, 15 March 2020, 135432

Accumulation of microplastics in typical commercial aquatic species: A case study at a productive aquaculture site in China

Fangzhu Wu [a, 1], Youji Wang [a, b, c, 1], Jonathan Y.S. Leung [d, e], Wei Huang [a, c], Jiangning Zeng [a, f], Yanbin Tang [a], Jianfang Chen [a, c], Aiqin Shi [c], Xiang Yu [a, g], Xiaoqun Xu [a], Huaguo Zhang [c, f], Liang Cao [g]

ELSEVIER
Science of The Total Environment
Volume 658, 25 March 2019, Pages 62-68

Microplastic pollution in the Maowei Sea, a typical mariculture bay of China

Jingmin Zhu [a], Qiang Zhang [a], Yanping Li [a], Shudan Tan [a], Zhenjun Kang [a], Xueying Yu [a], Wenlu Lan [b], Li Cai [c], Jingzhen Wang [a], Huahong Shi [d]

ELSEVIER
Environmental Pollution
Volume 280, 1 July 2021, 116960

Microplastic ingestion in reared aquaculture fish: Biological responses to low-density polyethylene controlled diets in *Sparus aurata* ☆

Carme Alomar [a], Marina Sanz-Martín [a], Montserrat Compa [a], Beatriz Rios-Fuster [a], Elvira Álvarez [a], Vincent Ripolles [a], José María Valencia [b, c], Salud Deudero [a]

[a] Instituto Español de Oceanografía, Centro Oceanográfico de Baleares, Muelle de Poniente s/n, 07015, Palma de Mallorca, Spain

[b] Laboratorio de Investigaciones Marinas y Acuicultura, LIMIA-Govern de Les Illes Balears, Port d'Andratx, Balearic Islands, Spain

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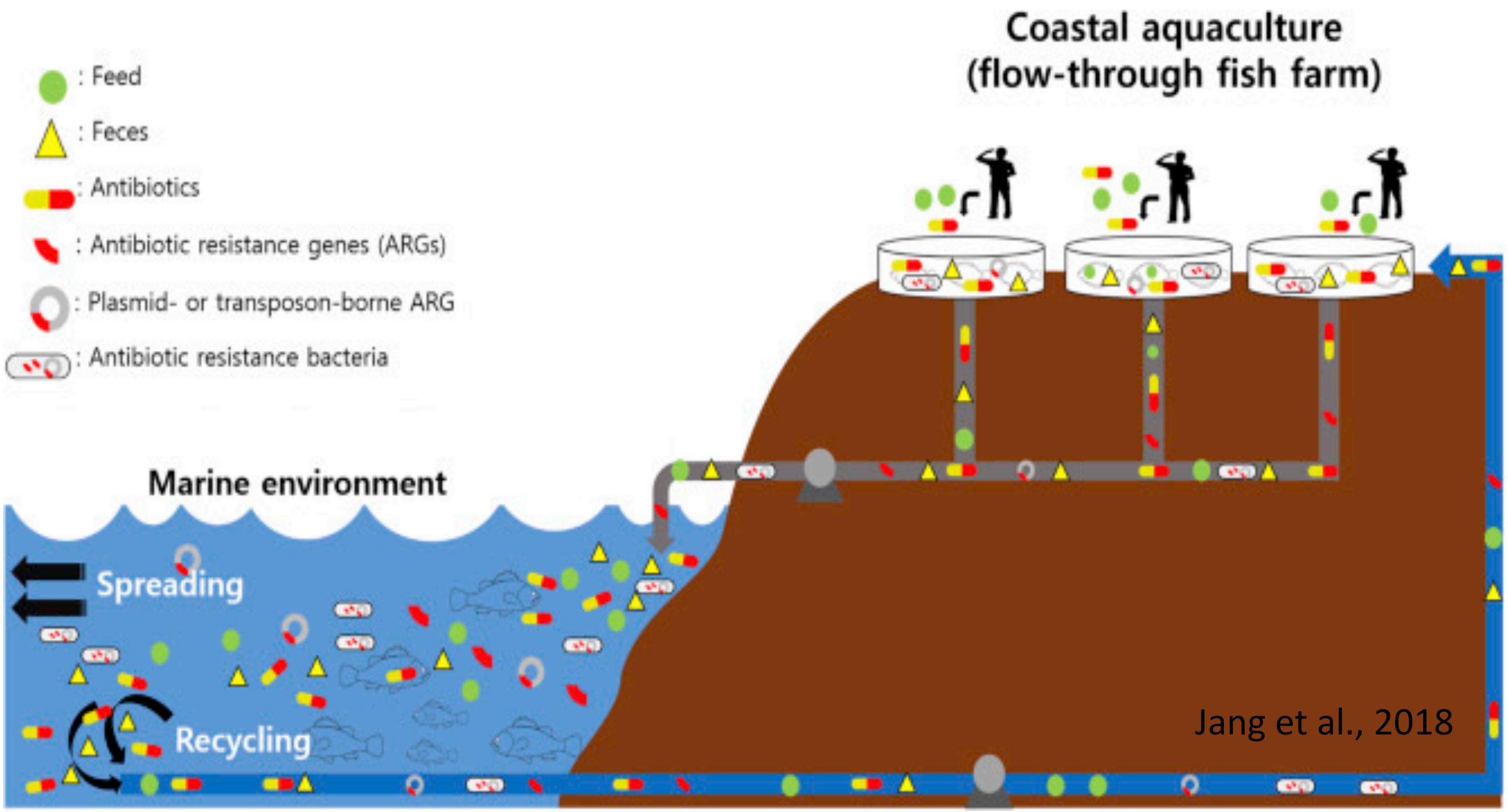
The wide use of antibiotics in aquaculture for therapeutic purpose can potentially lead to the prevalence of antibiotic resistance genes (ARGs).

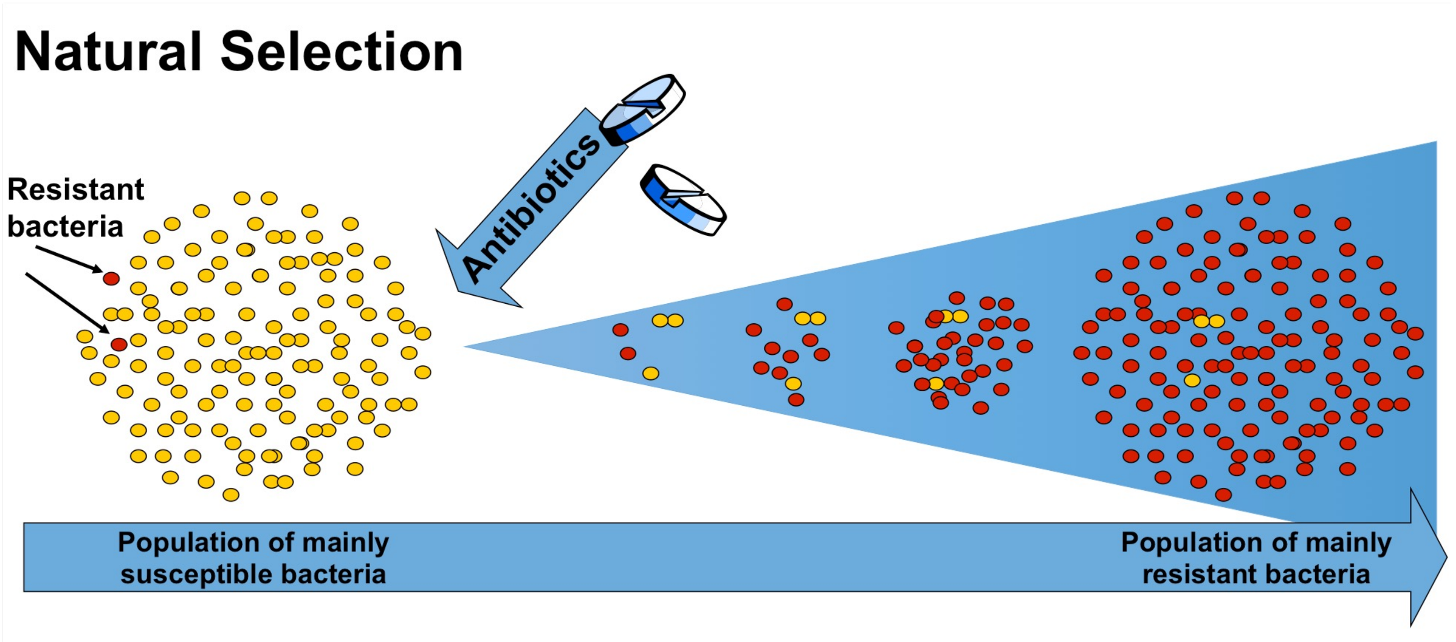


Drugs contained in fish feed can persist in the aquatic environment for a long time and rapidly spread throughout water systems, exerting selective pressure in ecosystems.

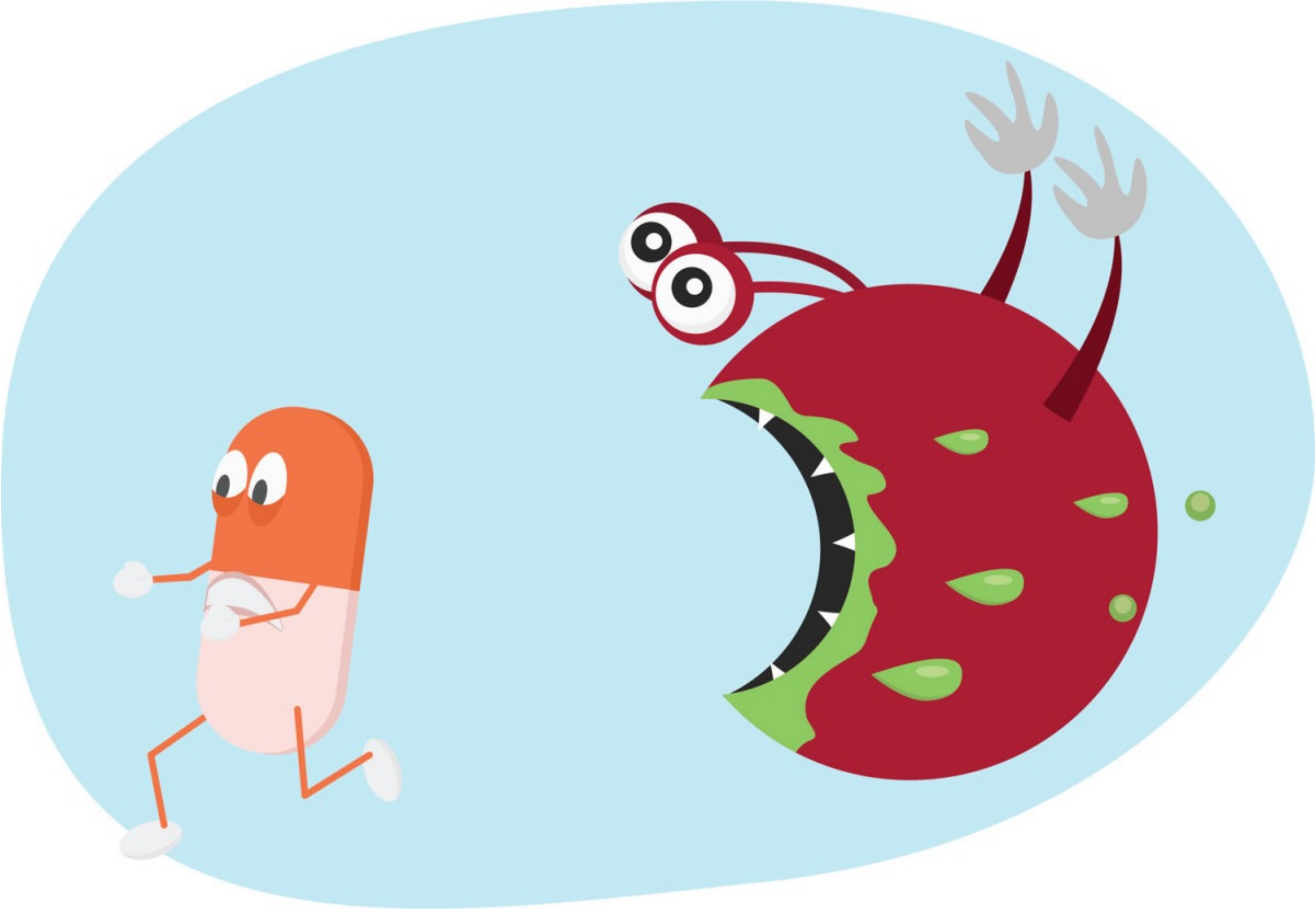
Antimicrobial resistance

Antimicrobial Resistance (AMR) refers to microorganisms (bacteria, fungi, viruses, and parasites) that have acquired resistance to antimicrobial substances.

While this phenomenon can occur naturally through microbial adaptation to the environment, it has been promoted by inappropriate and excessive use of antimicrobials.



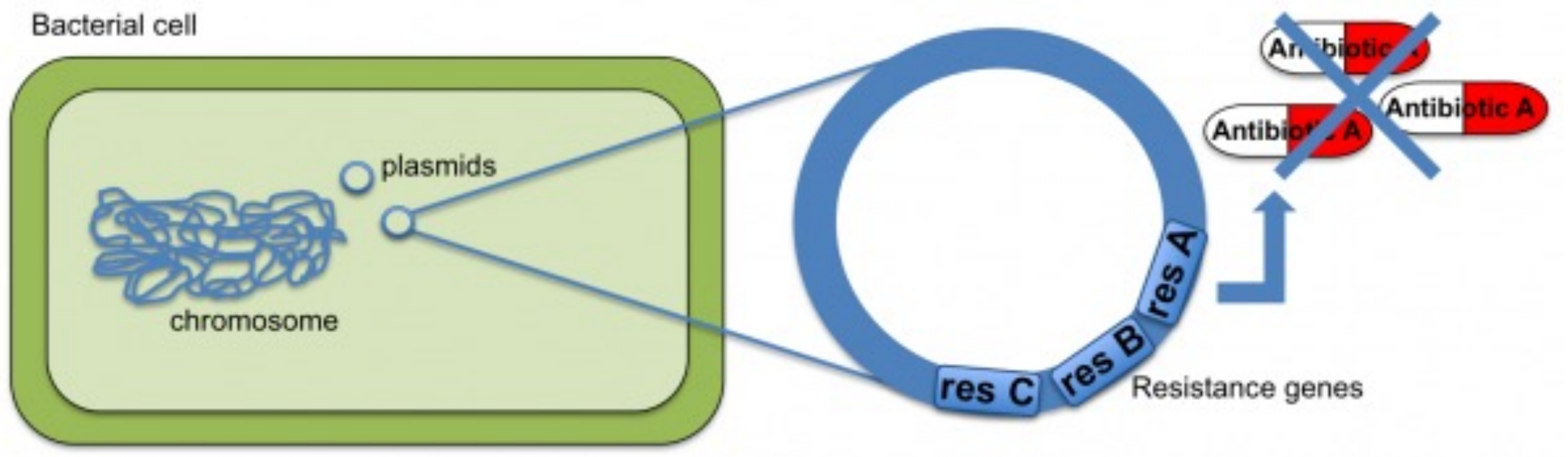
Increasing global **Antimicrobial Resistance (AMR)** is a major threat to human and animal health



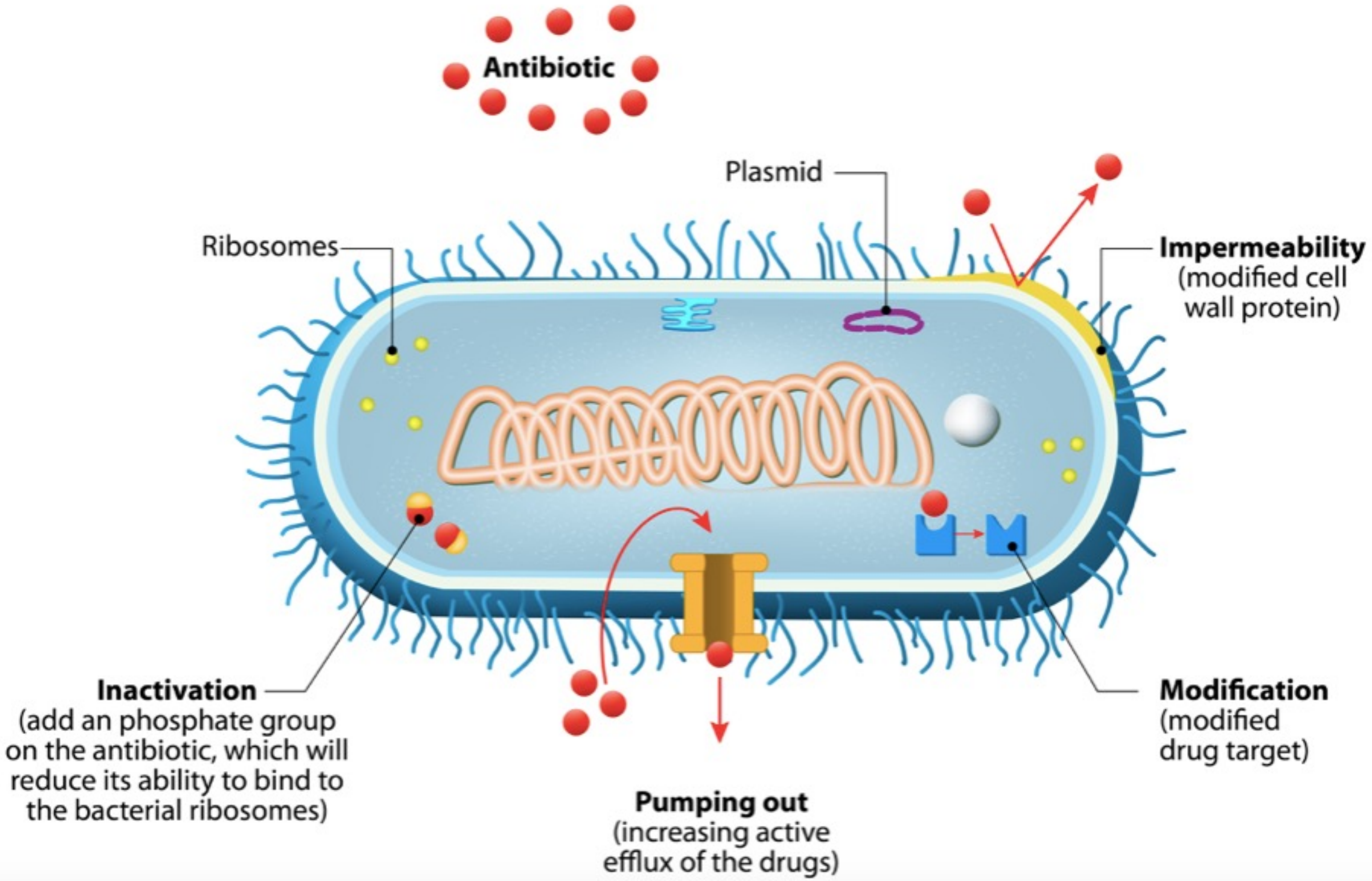
It **threat** modern human and veterinary medicine and **undermines** the **safety** of our **food** and **environment**.

PROTECT ANTIBIOTICS
so they can protect you

The bacterial chromosome is made up of DNA and stores all the information that a bacterial cell needs to carry out its normal functions. In addition to the chromosome, bacteria can have small circles of DNA called plasmids that also contains genes.



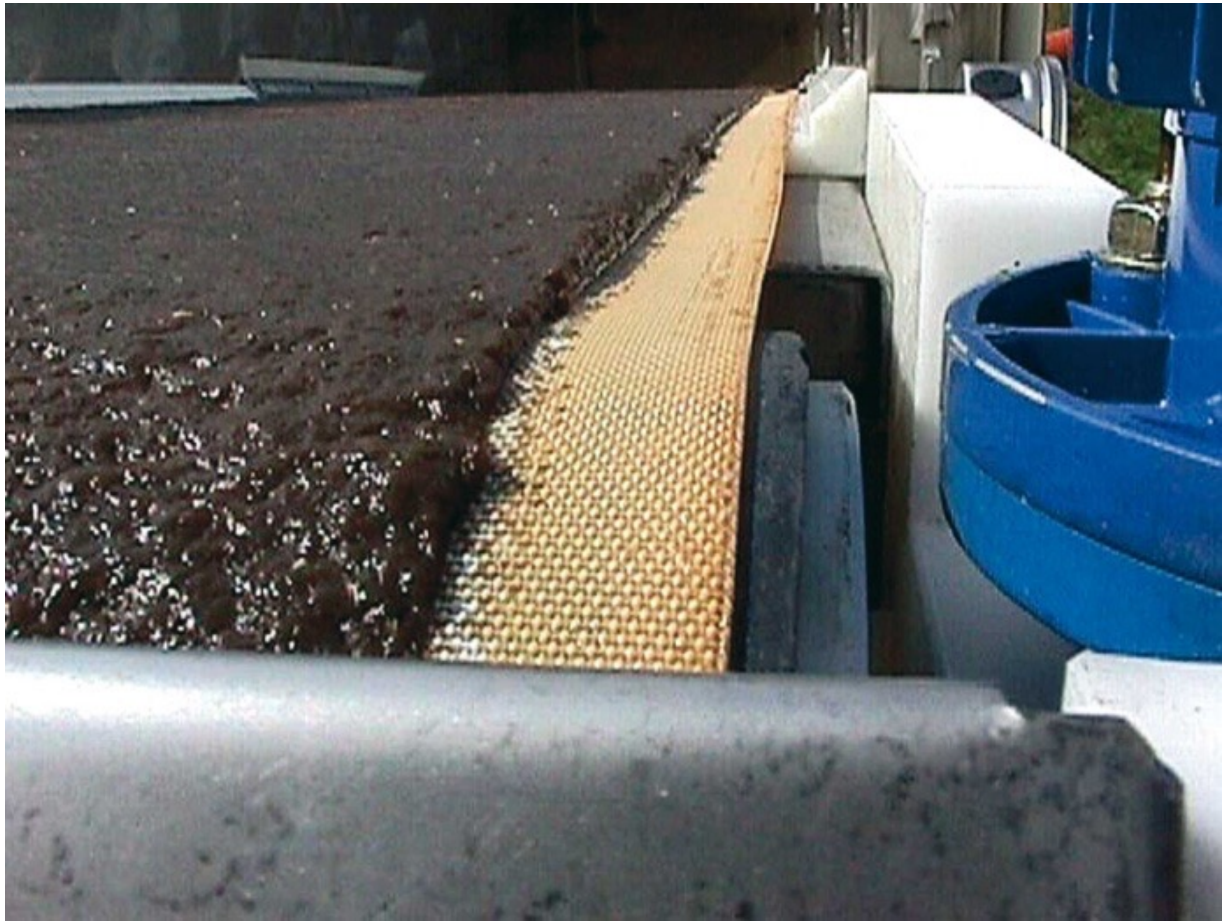
MECHANISMS OF ANTIMICROBIAL RESISTANCE



AMR in closed Aquaculture Systems

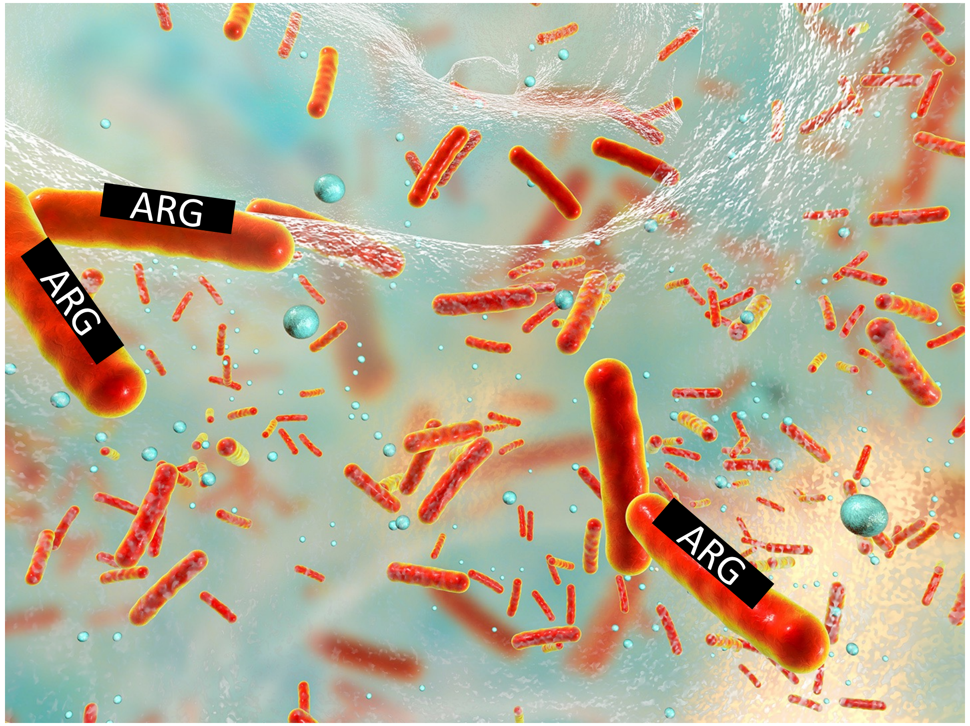
Closed flow-through systems produce wastewater containing suspended solids and nitrogen, phosphorous, and high microbial loads, which will either enter the municipal wastewater system after a number of treatment steps, flow to wetlands, or be treated to produce a sludge that **can be added to land as a fertilizer**.

This use of **aquaculture sludge** has numerous **implications for the concentration and spread of AMR** genes onto food crops and into the soil system.



Near zero-discharge recirculating aquaculture systems (RASs) are designed to produce species at high density and minimize environmental impact by effectively managing, collecting, and treating wastes that accumulate during fish growth for both freshwater and marine systems.

Li et al. (2017) found **that biofilms from RAS** mixed bed biofilters are a reservoir for antibiotic resistance genes, including tetO, qnrA, and tetE.



Biofilms, however, **are generally resistant to penetration by antibiotics**, which, makes the treatment of pathogens difficult (Blancheton et al., 2013).

THANKS FOR YOUR ATTENTION!

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