

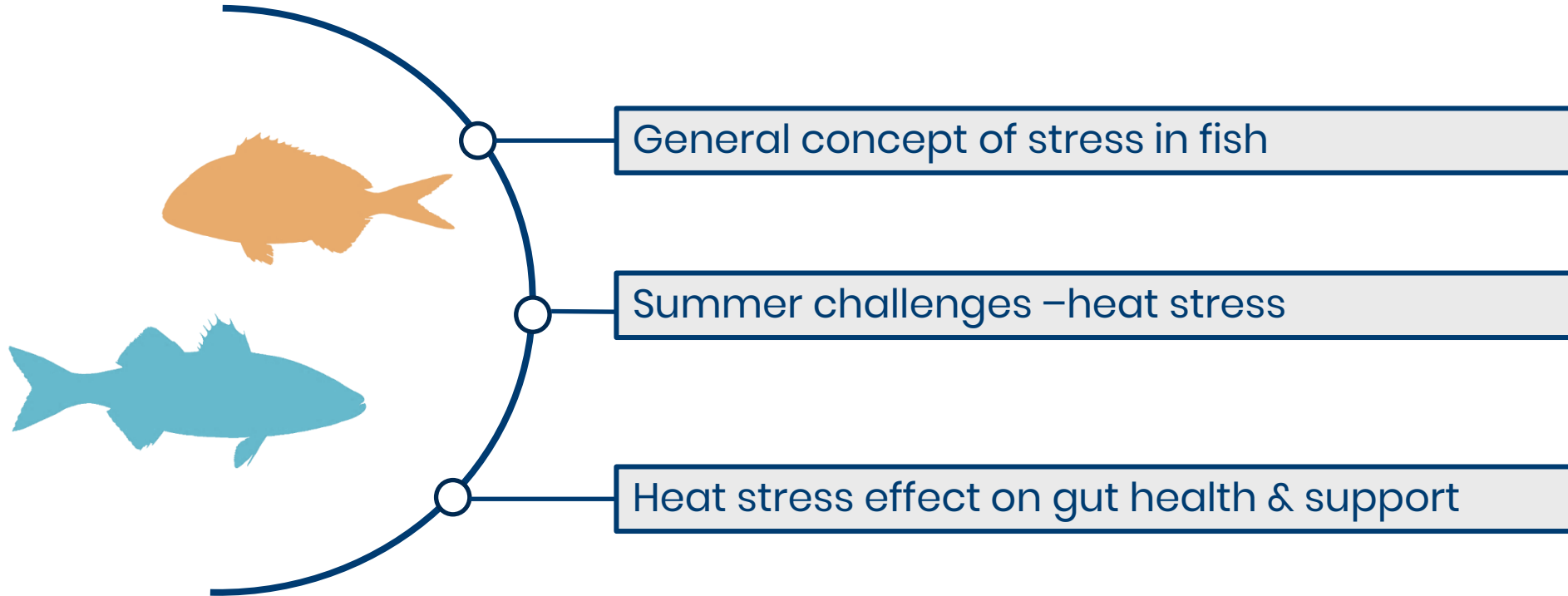


Heat Stress in Fish

A Hot Topic in Summer for Fish Farmers

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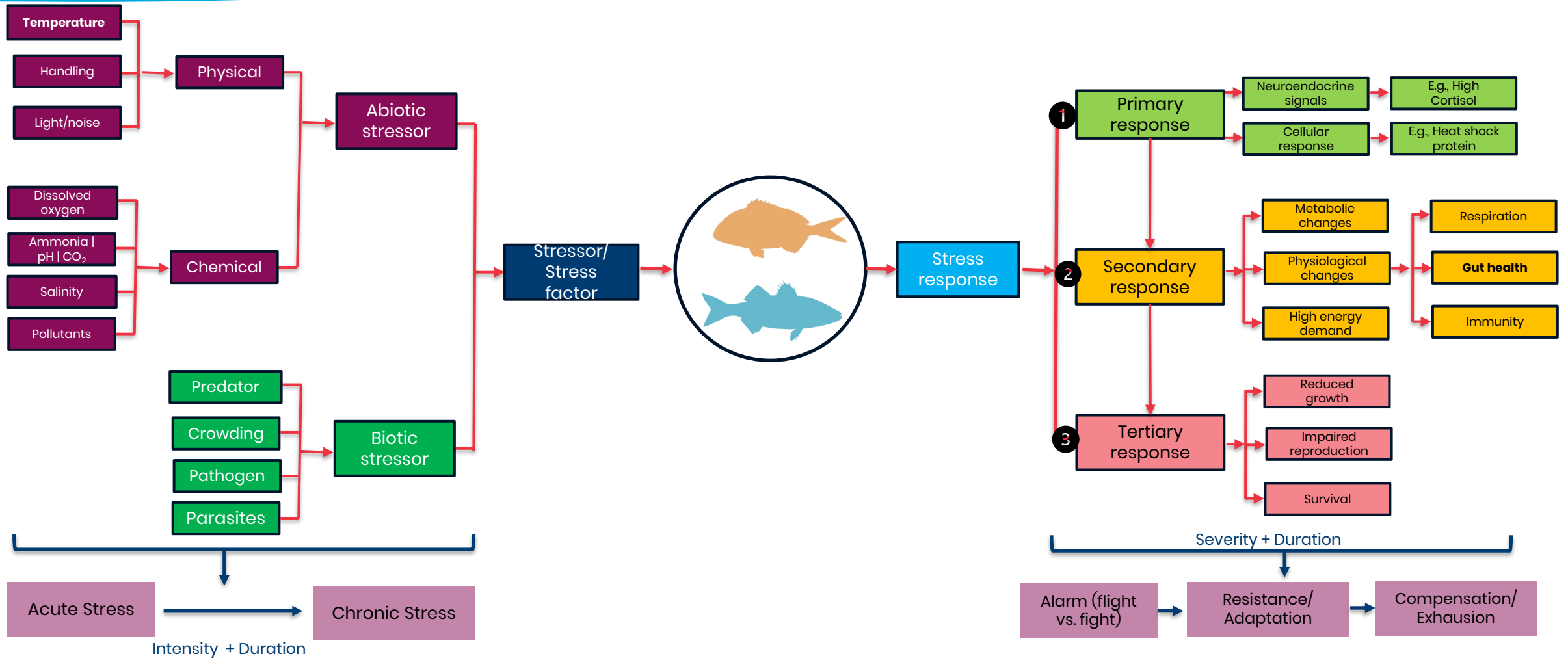
Content overview



What is stress?

- Stress is the nonspecific response of the body to any demand placed upon it (Selye, 1950)
- Stress is a condition where an environmental demand exceeds the natural regulatory capacity of an organism (Koolhaas et al., 2011)

Stressors and stress response in fish

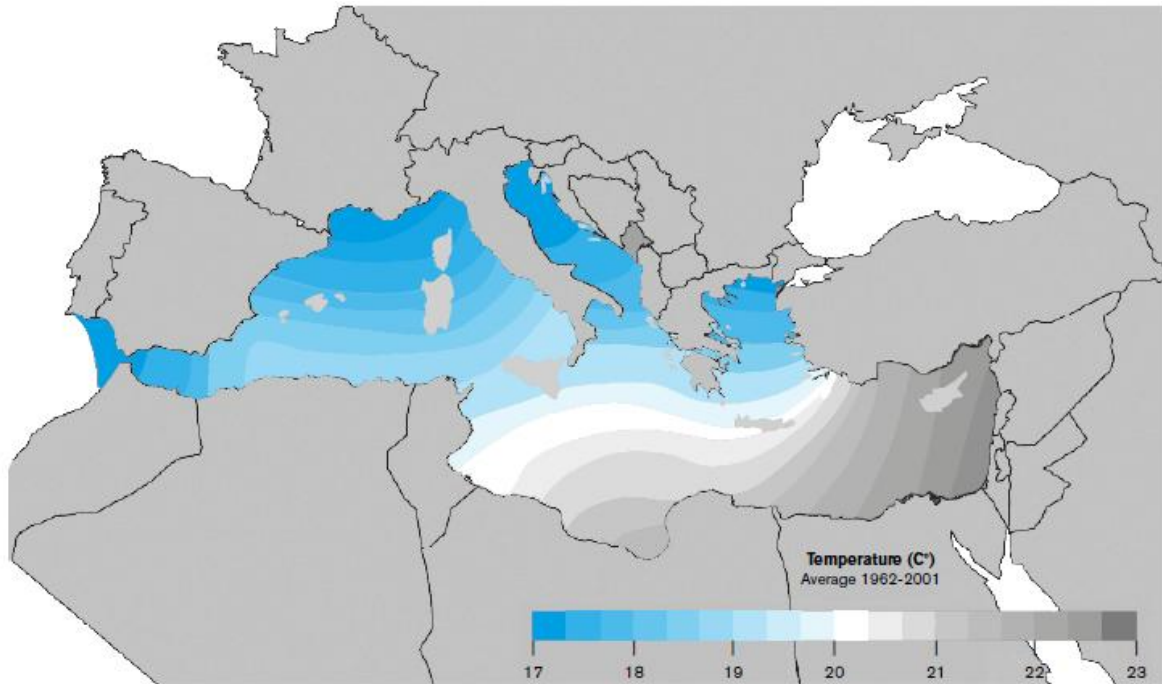


Why water temperature affects fish performance?

- Fish are **ectothermic animals**
 - Their body temperature reflect surrounding water temperature
 - **Survival, feed intake, growth and reproduction depends on water temperature**
- Thermal production metrics in fish farming
 - Appropriate to express as Thermal growth coefficient (TGC)
 - Duration of crop should be expressed as degree days (temp x days)
- **In open aquaculture systems, water temperature is influenced by diurnal and seasonal regime**

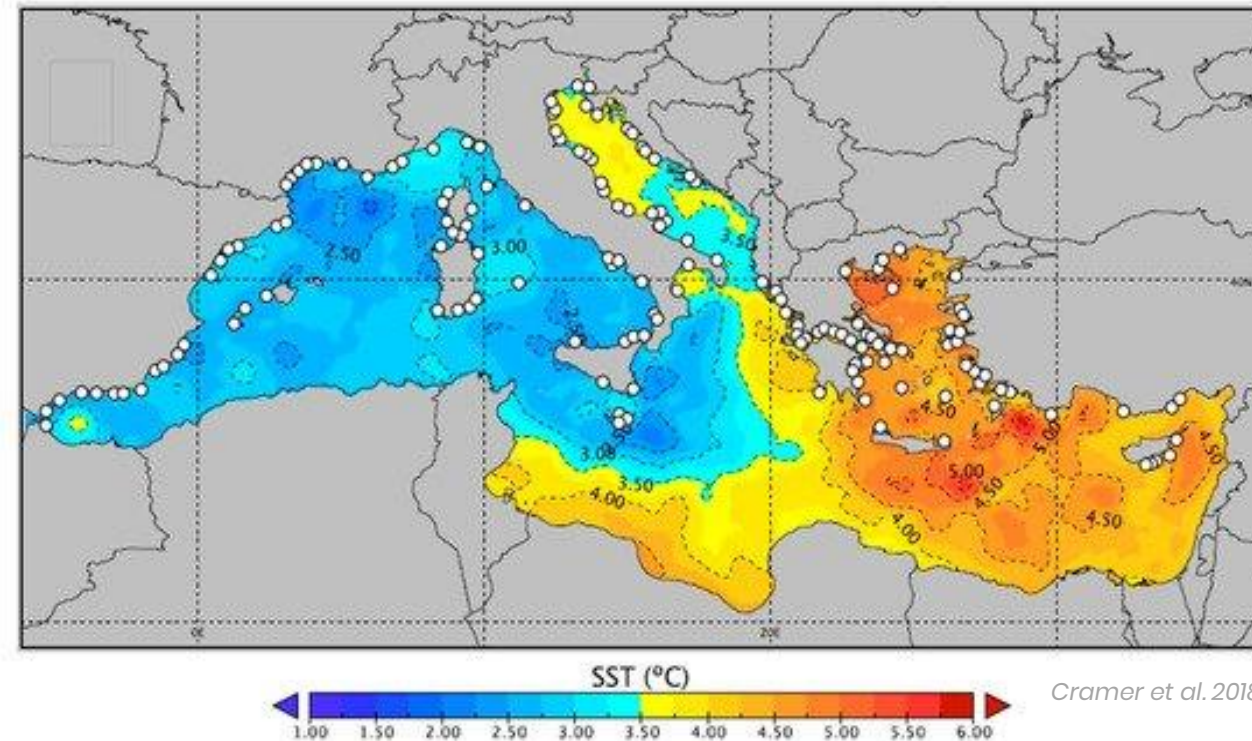
Mediterranean sea temperature is shifting upward

Average surface temperatures of the Mediterranean Sea



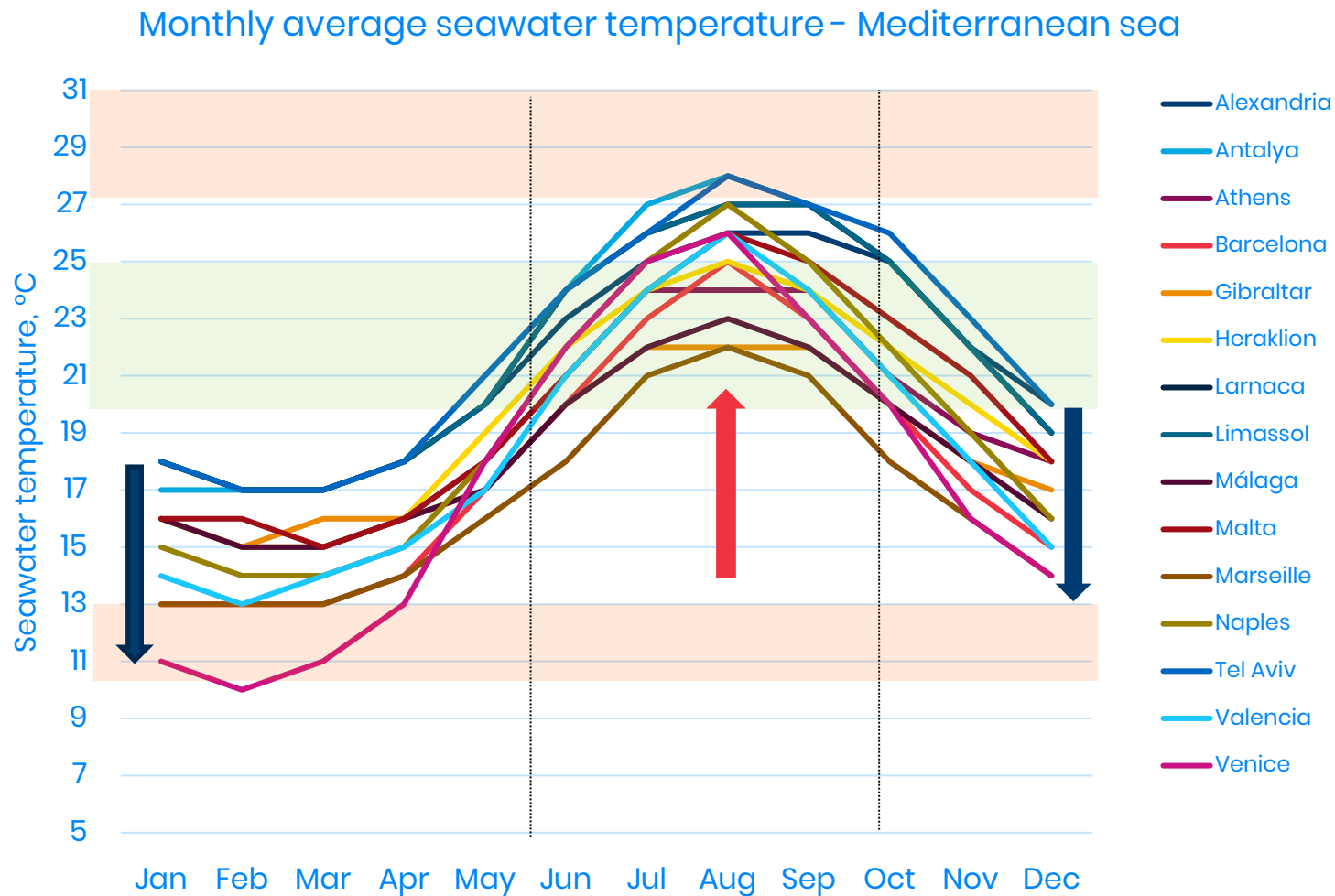
Source: Lange, 2020;

Temperatures rise expected in Mediterranean Sea



Cramer et al. 2018

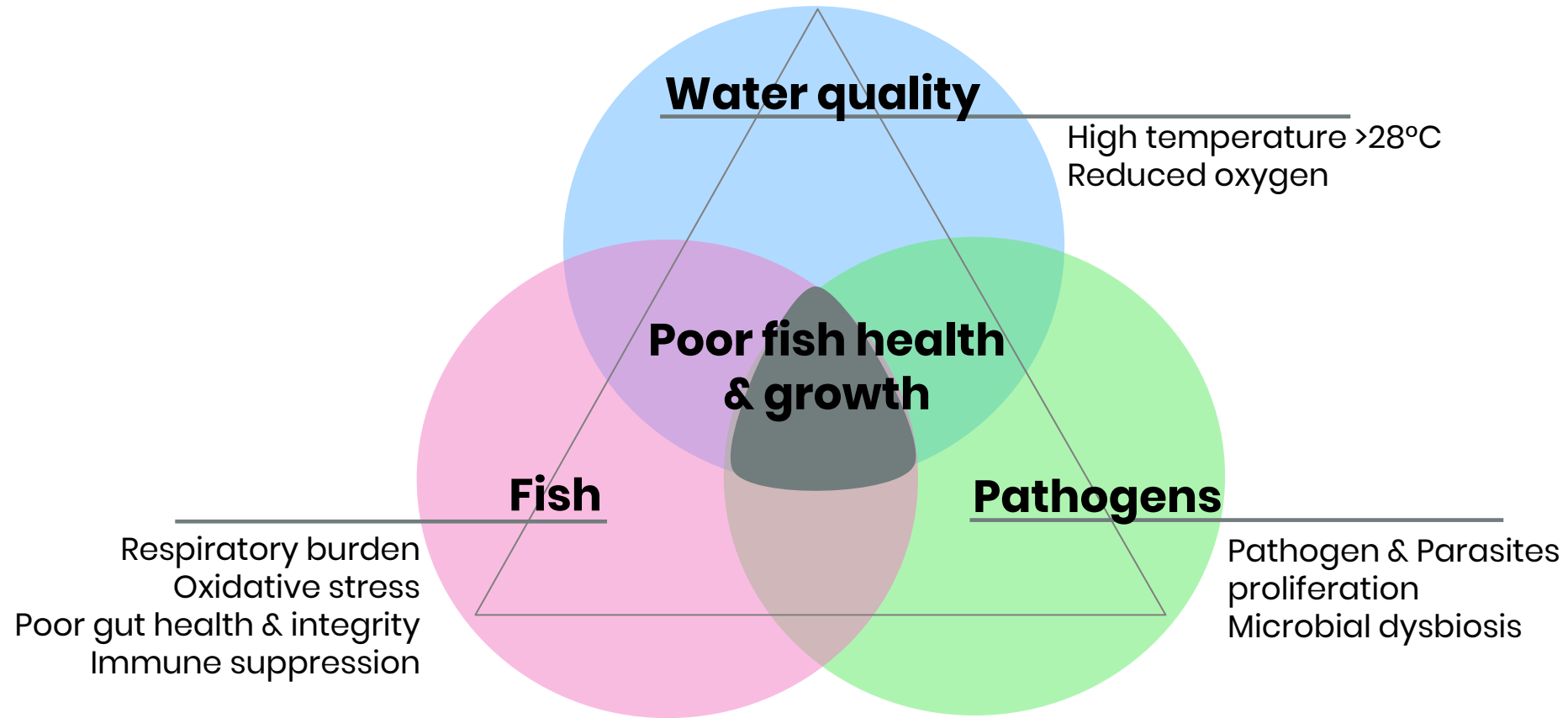
Seasonal water temperature in Mediterranean sea



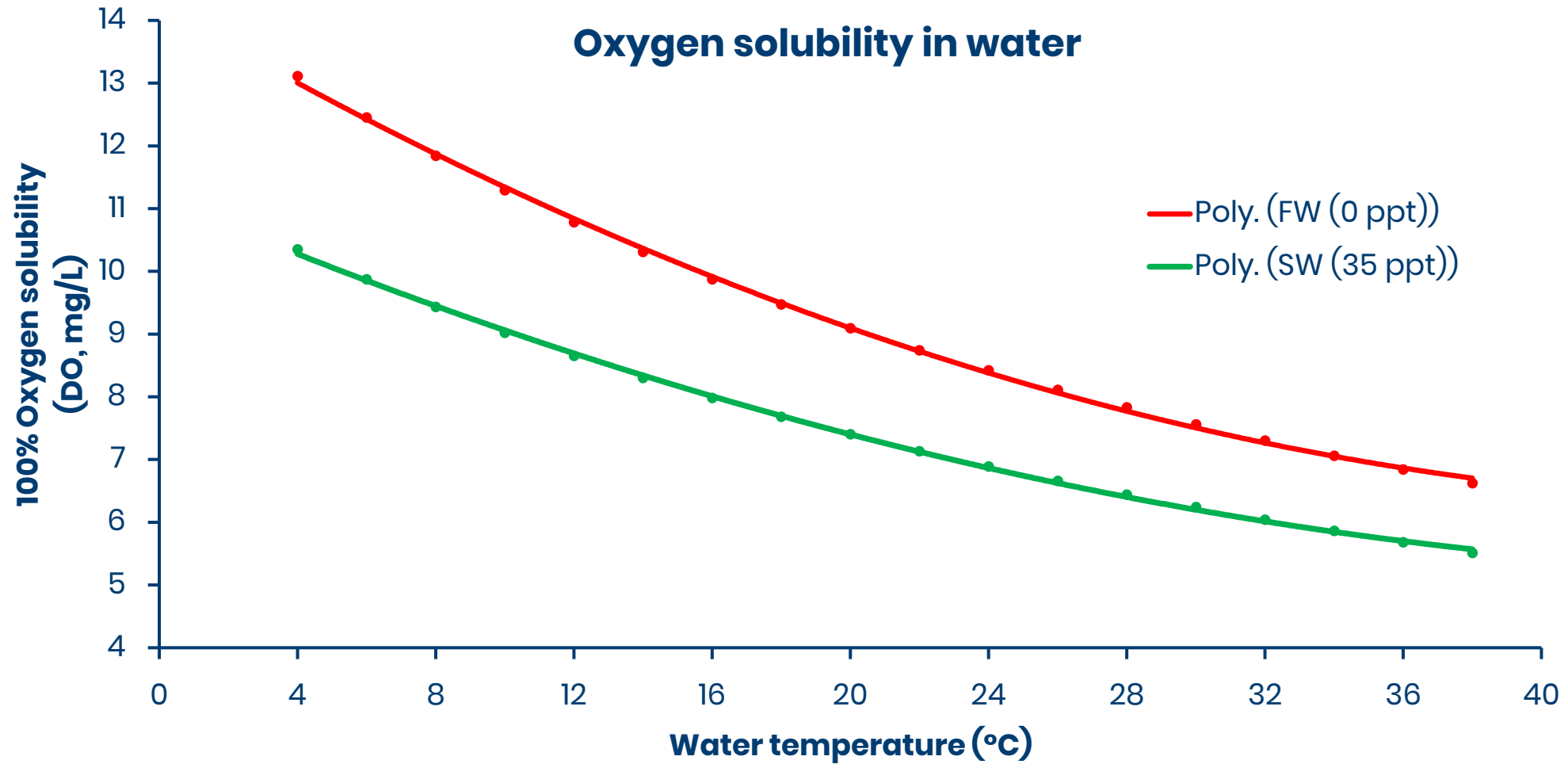
Source: seatemperature.org

Seasonal water temperature variation of ± 10 °C

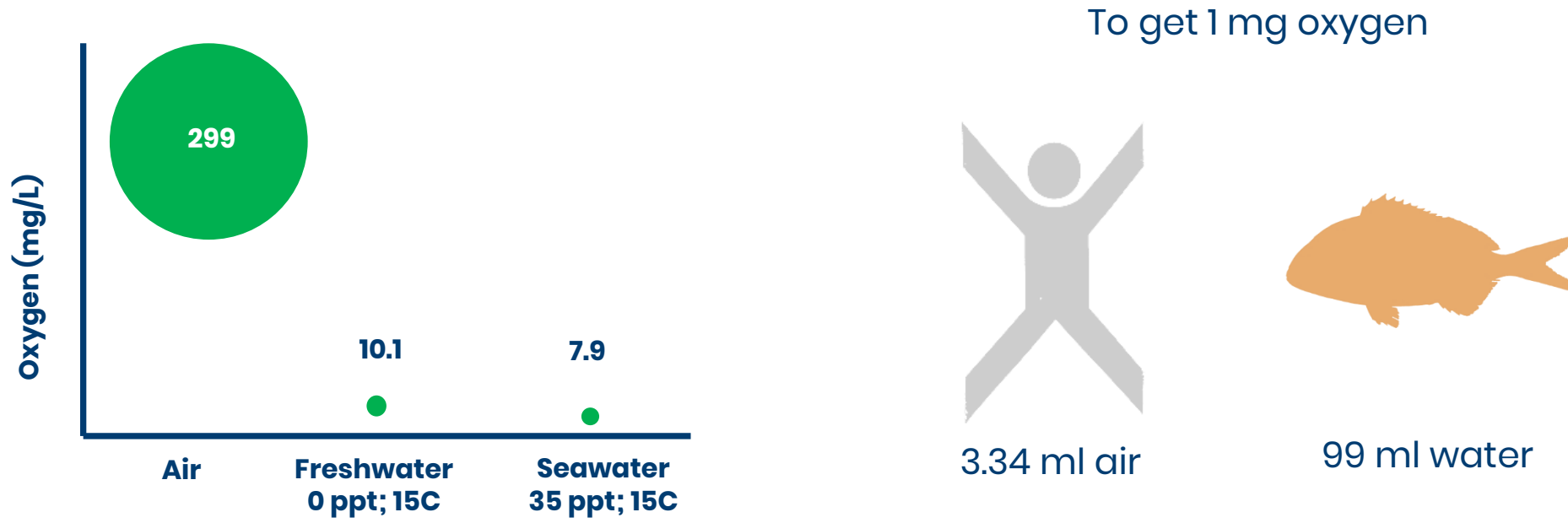
Summer challenges – heat stress



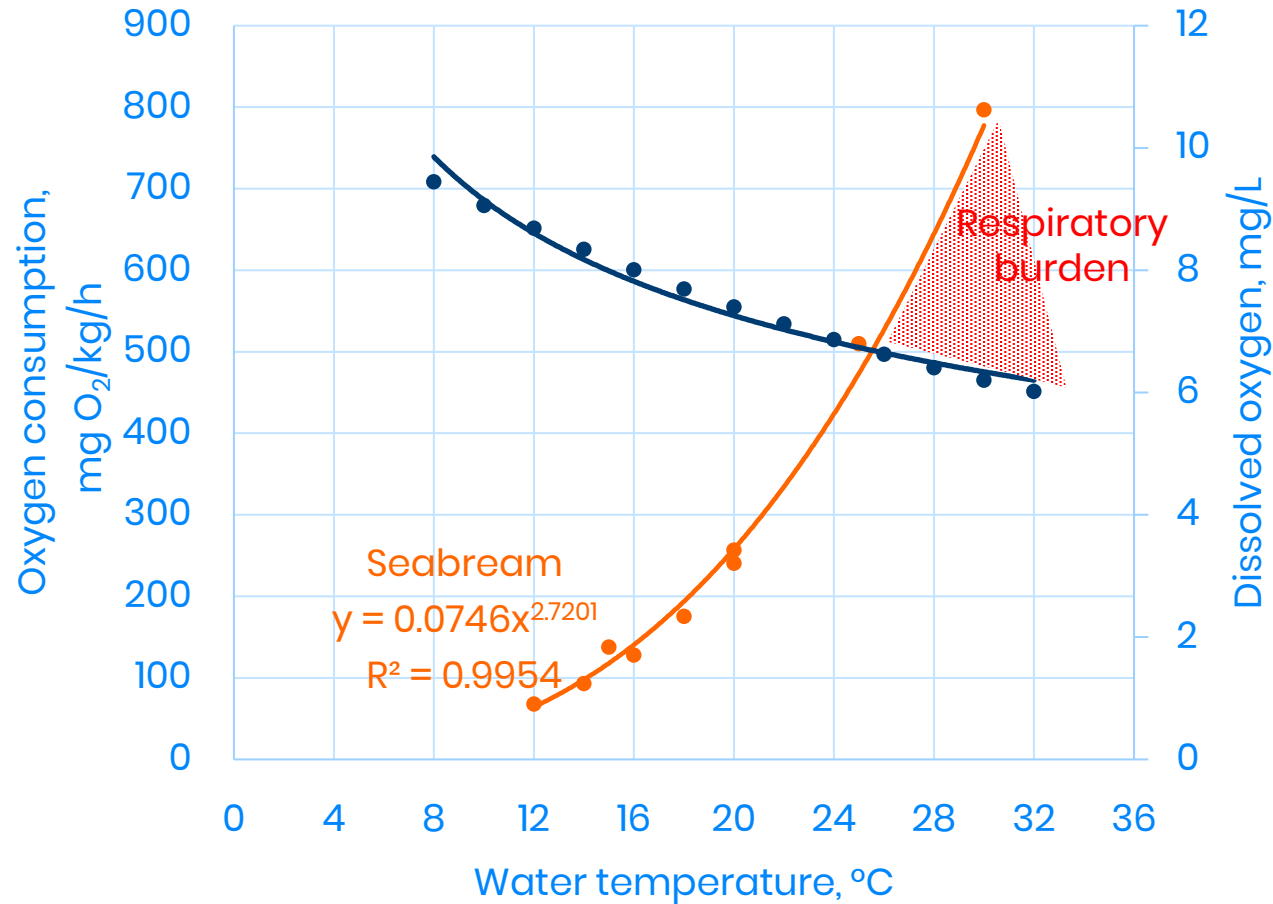
DO level in water is related with temperature & salinity



Oxygen in water is 30 times lower than in air!



Gasping fish in hot water

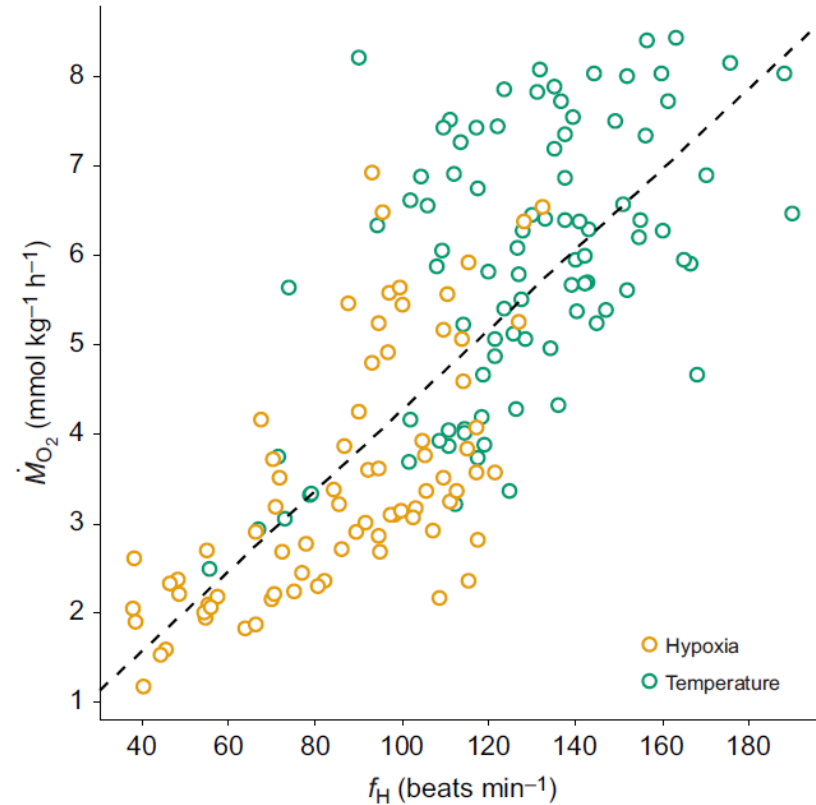
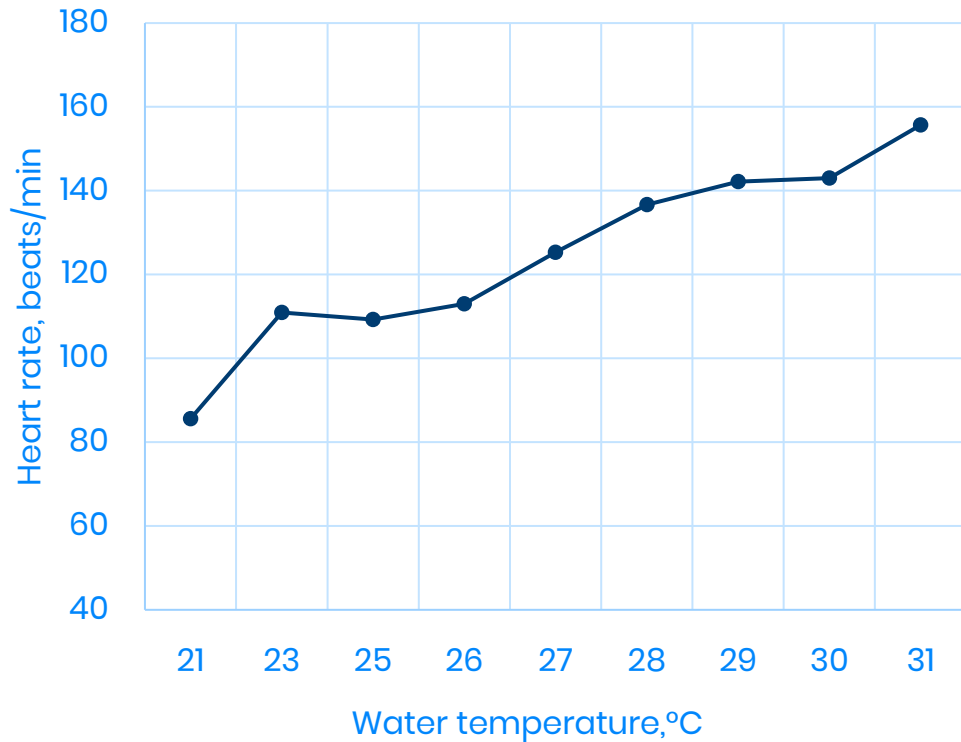


Data from Remen et al., 2015 & Kir, 2020

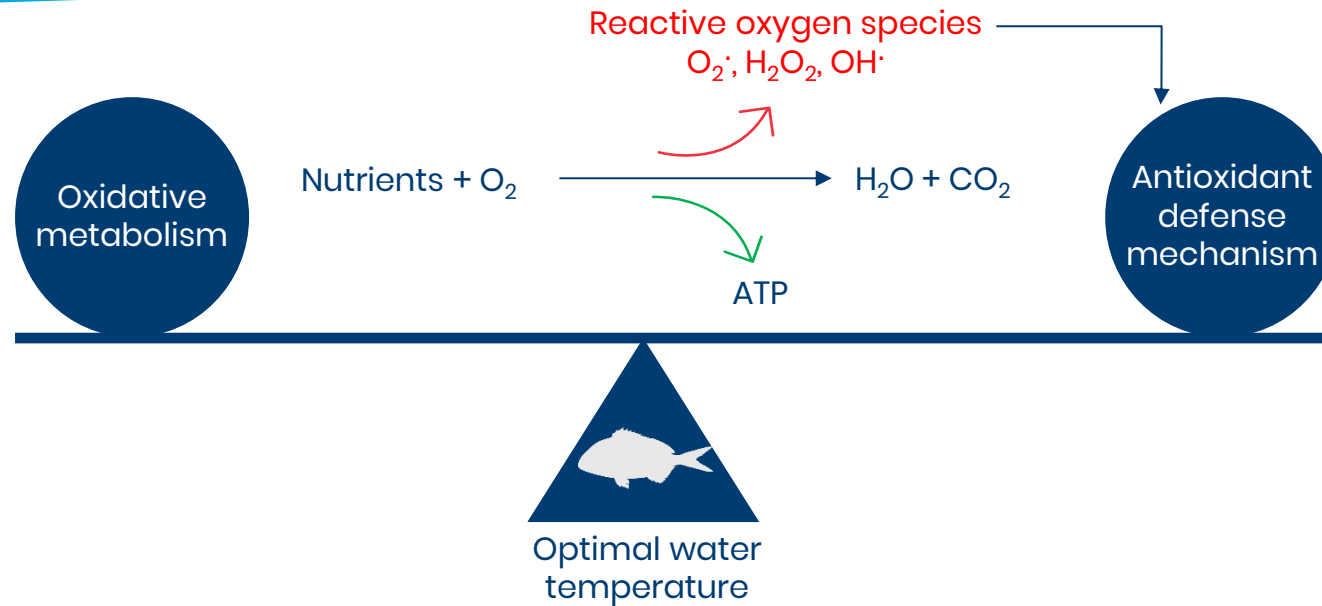
- Increase in water temperature - increases oxygen demand of fish, and at same-time dissolved oxygen level drop in water
- Imbalance in oxygen demand and supply - leads to respiratory burden
- Gill & heart function are accelerated for O₂ uptake and CO₂, ammonia excretion
- Overload of gill function can result in loss of mucus, which can further compromise gill health → complex gill syndrome

Supporting fish respiration in summer

Effect of temperature in unfed seabream

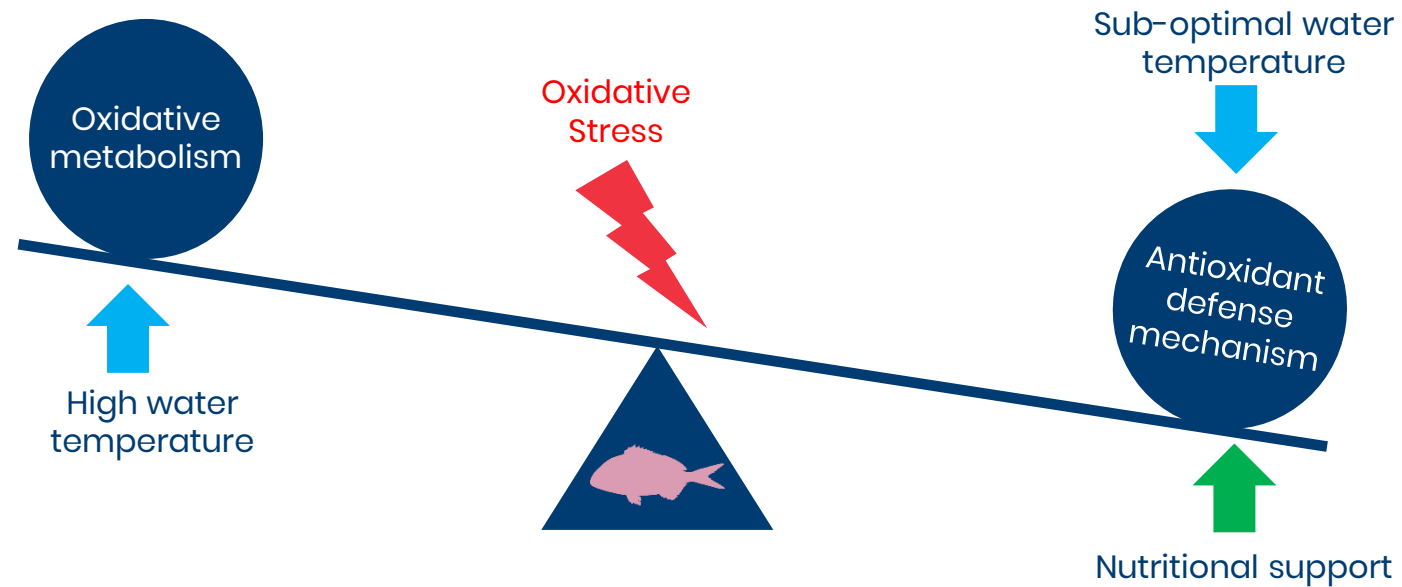


Fine balance of oxidation and antioxidant



- The chemistry of life in essence, is converting food into growth and energy through oxidative metabolism
- Free radicals/ROS are produced through oxidative process, which are neutralized through antioxidant defense mechanism
- Antioxidant defense – Enzymatic mechanism & non-enzymatic mechanism
- Endogenous enzymatic antioxidant mechanism – Superoxide dismutase, Catalase, Glutathione peroxidase
- Non-Enzymatic mechanism – Vitamin E, C, carotenoids etc.

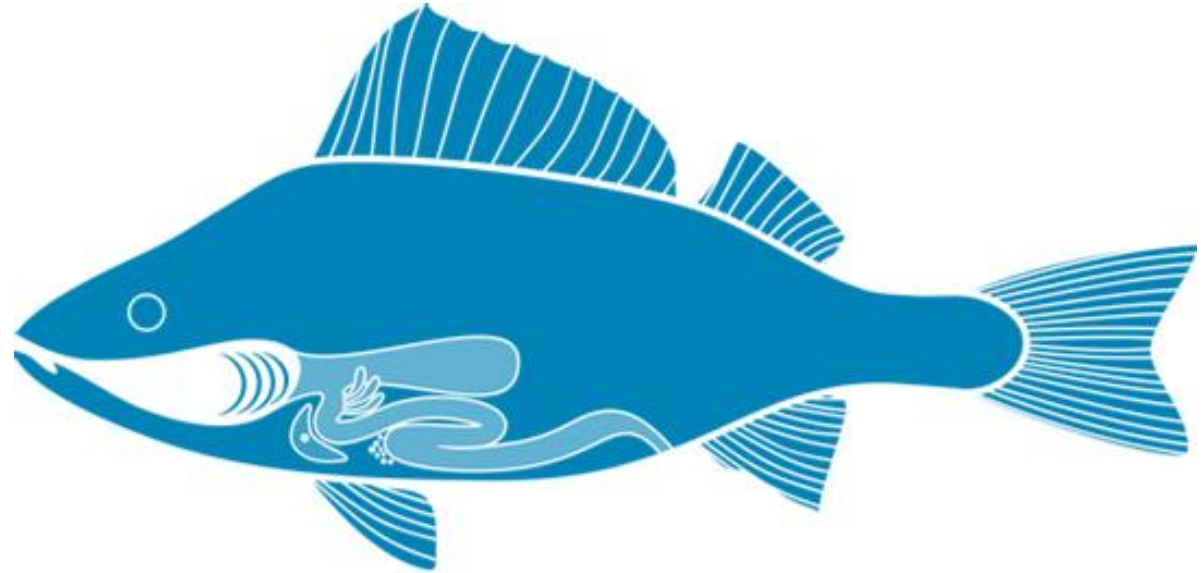
Heat stress in fish induces oxidative stress



Where is the money made in fish?



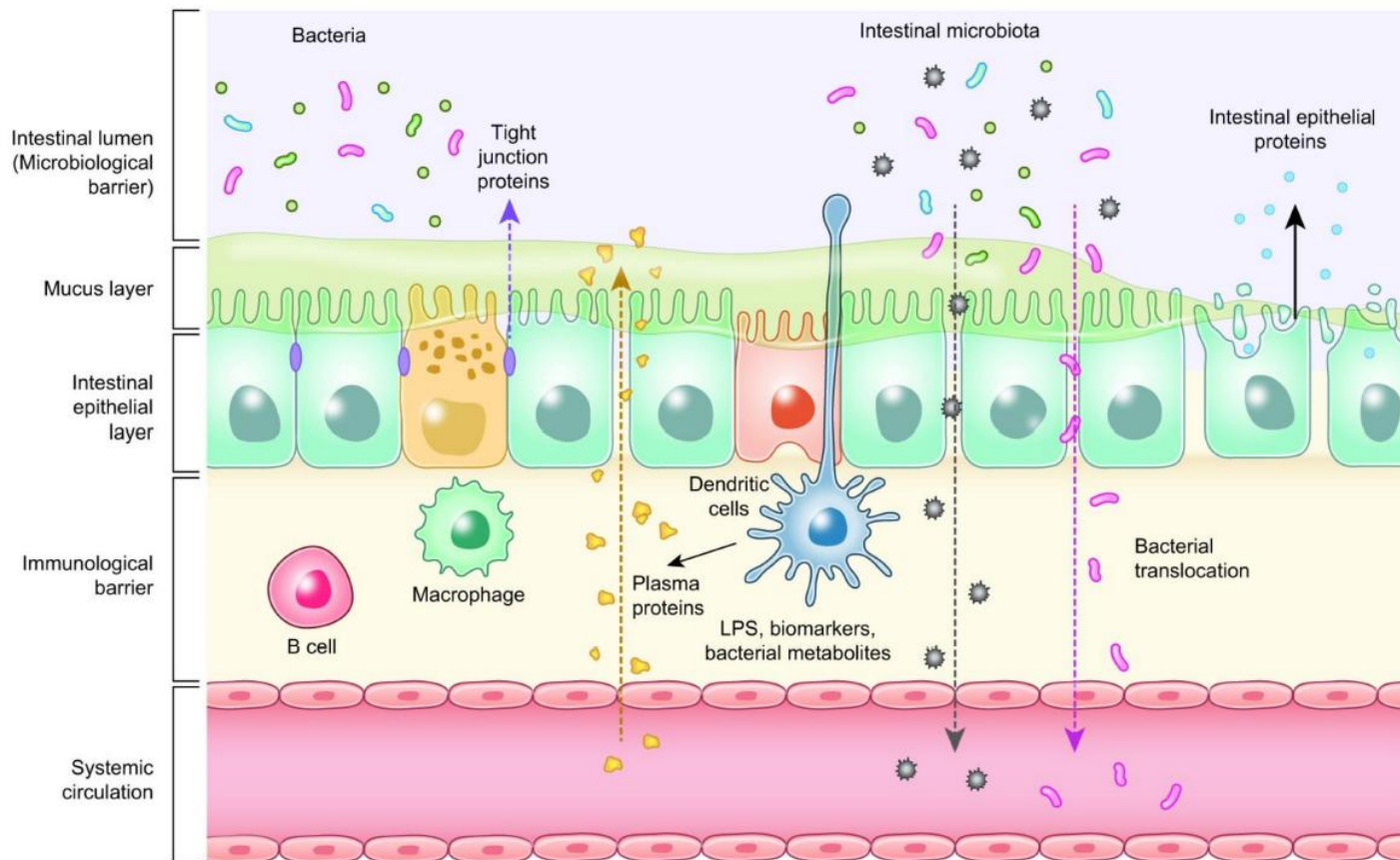
Feed



Fish

Heat stress affects gut health in fish

Intestinal inflammation leads to poor gut integrity



Shehata et al., 2021

Histomorphological changes

- Mucosal loss
- Short and thin villi, reduced surface area
- Gut barrier compromised

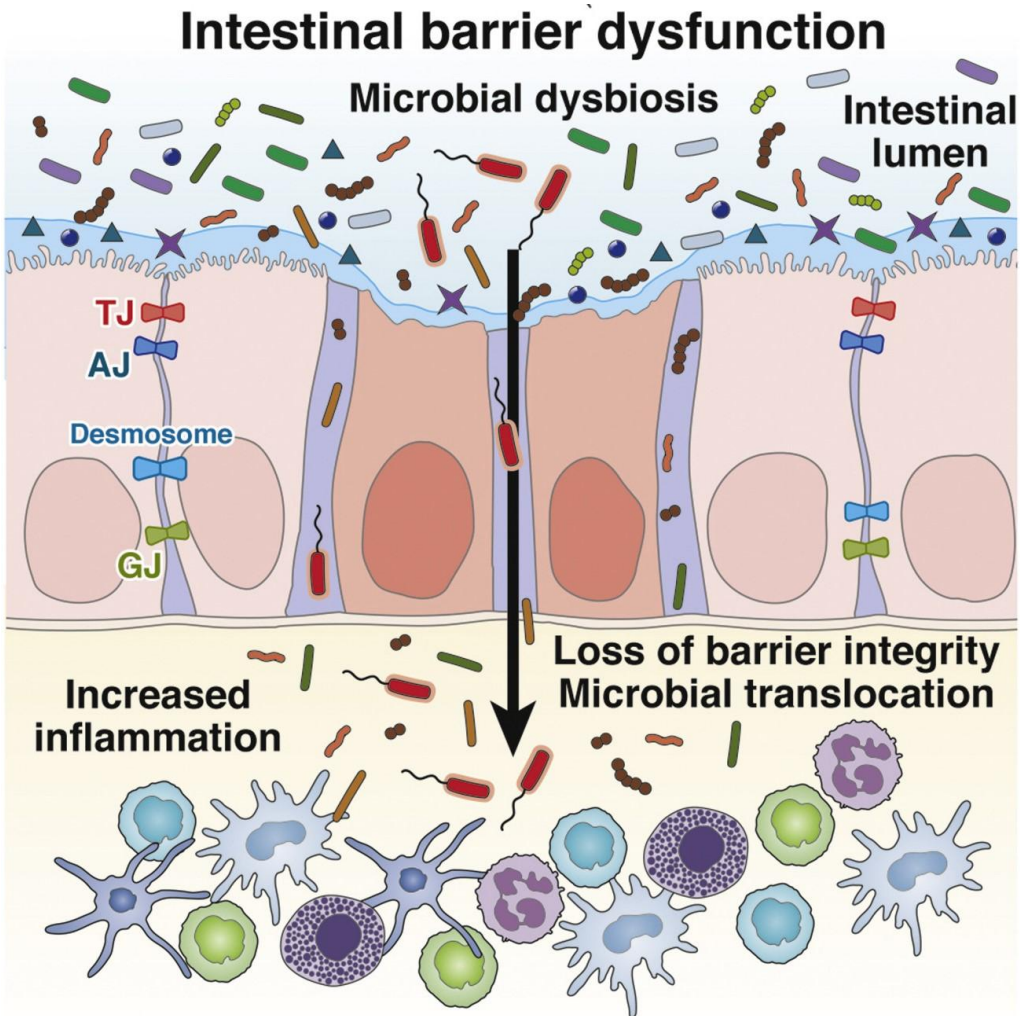
Functional changes

- Reduced enzyme activity
- Reduced nutrient absorption
- Increased loss of nutrients
- Reduce nutrient digestibility

Immunological changes

- Pro-Inflammatory
- Tight junction disruption
- Bacterial translocation

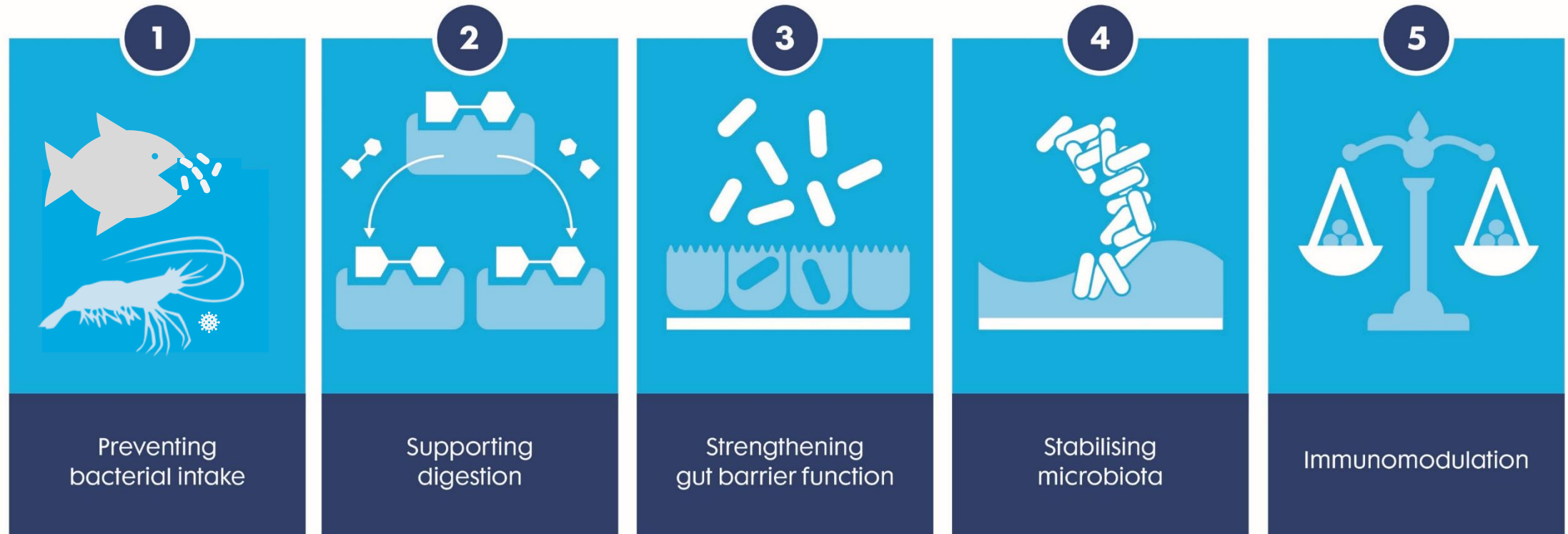
Tackling chronic gut inflammation through diet



Ghosh et al., 2021

- Intestinal inflammation and loss of tight junction can result in leaky guts and trigger anti-inflammatory response
- Gut health enhancing compound like organic acids can help to strengthen enterocytes and gut integrity and optimize gut microbiome

Preventive gut health pillars



←—————→
Organic acids

What are organic acids?

- Organic acids are **carboxylic acids** – Mono-, Di-, Tri-carboxylic acids
- 'Organic' – as all organic acids contain a 'Carbon' molecule, unlike inorganic acids (e.g., HCl)
- Depending on the number of carbon molecules, organic acids are classified as Short chain fatty acids (**SCFAs**, ≤ 6) and Medium chain fatty acids (**MCFAs**, $>7 - 12$)
- Organic acids are **present in nature | Beneficial gut microbes produce** SCFAs like acetic acid, propionic acid and butyric acids
- **Organic acids in animal nutrition have several applications with functional benefits** (feed preservation, gut health and production efficiency)

Short chain- and medium chain- fatty acids

Class	Organic acid	Carbon no.	Molecular mass, g/mol	pKa (acid dissociation value)
SCFA	Formic acid	C1	46.03	3.75
SCFA	Acetic acid	C2	60.05	4.76
SCFA	Propionic acid	C3	74.08	4.88
SCFA	Butyric acid	C4	88.11	4.82
SCFA	Valeric acid	C5	102.13	4.84
SCFA	Caproic acid	C6	116.16	4.88
MCFA	Caprylic acid	C8	144.21	4.89
MCFA	Capric	C10	177.26	4.90
MCFA	Lauric acid	C12	200.32	5.30

Bacterial pathogens in aquaculture

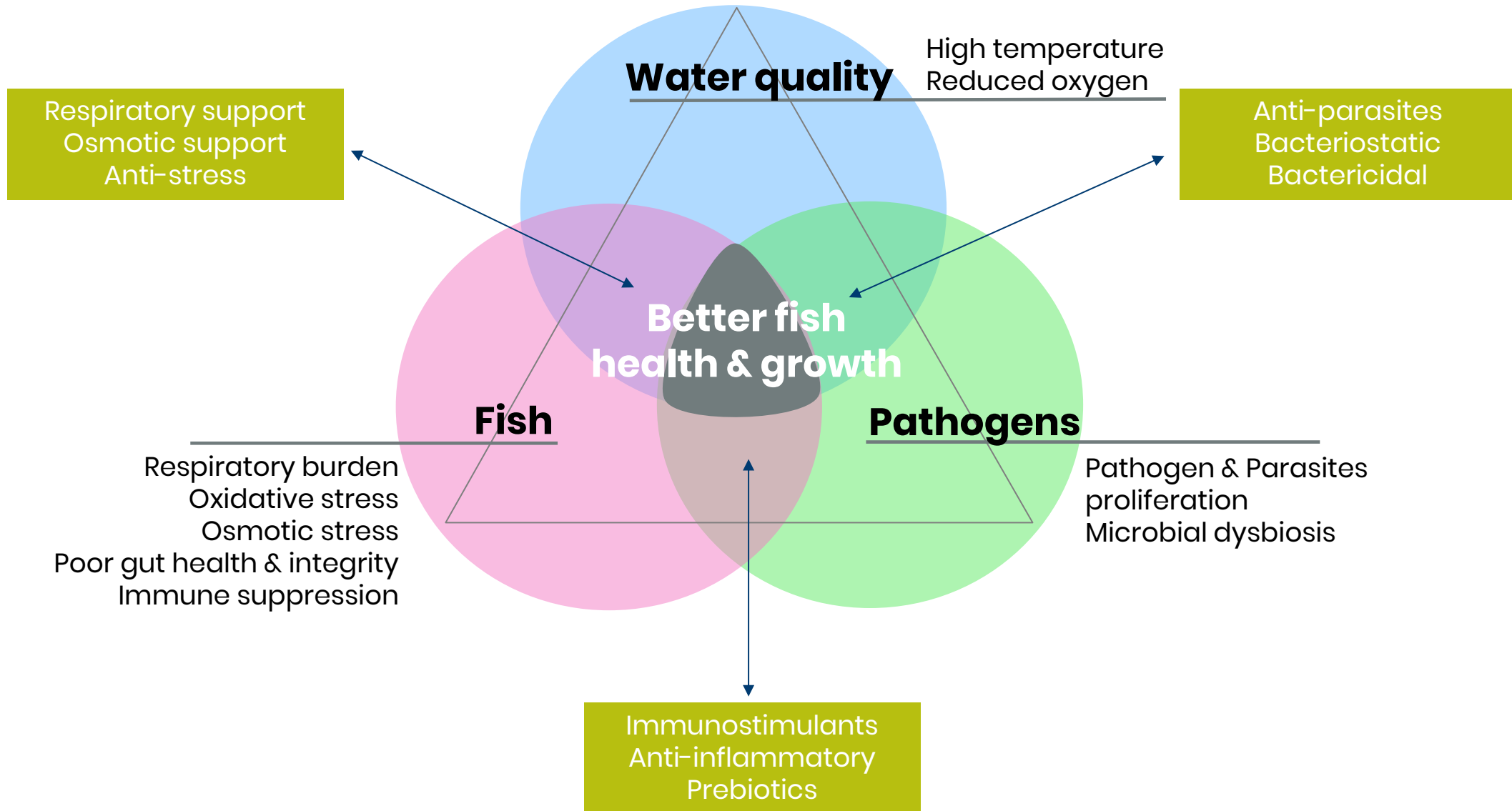
Gram negative pathogens	Gram positive pathogens
<i>Vibrio spp.</i>	<i>Streptococcus spp.</i>
<i>Aeromonas spp.</i>	<i>Lactococcus spp.</i>
<i>Pseudomonas spp.</i>	<i>Enterococcus spp.</i>
<i>Flavobacterium spp.</i>	<i>Erysipelothrix spp.</i>
<i>Piscirickettsia spp.</i>	* <i>Mycobacterium spp.</i>
<i>Yersinia spp.</i>	* <i>Renibacterium spp.</i>
<i>Edwardsiella spp.</i>	* <i>Nocardia spp.</i>
<i>Photobacterium spp.</i>	
<i>Francisella spp.</i>	
<i>Listonella spp.</i>	
<i>Tenacibaculum spp.</i>	

*Intracellular pathogens

Anti-bacterial effect of organic acids

	Gram-negative bacteria	Gram-Positive bacteria
Formic acid	+++	+
Citric acid	++	-
Sorbic acid	++++	+++
Benzoic acid	++++	++
Lactic acid	+++	-
Propionic acid	++	+
Acetic acid	+	+
Fumaric acid	++	+
C8	+++++	+++
C10	+++++	+++
C8, C10 mix	+++++	++++
C12	-	+++++
C8, C10, C12 mix	++++	+++++

Dietary support for fish to reduce impact of heat stress



Thank you