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Identification of Key challenges Facing Sustainable Fisheries and Aquaculture

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Project: 101129136 — SustainaBlue — ERASMUS-EDU-2023-CBHE

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Outline

01 Environmental pressures

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05 Governance & policy gaps

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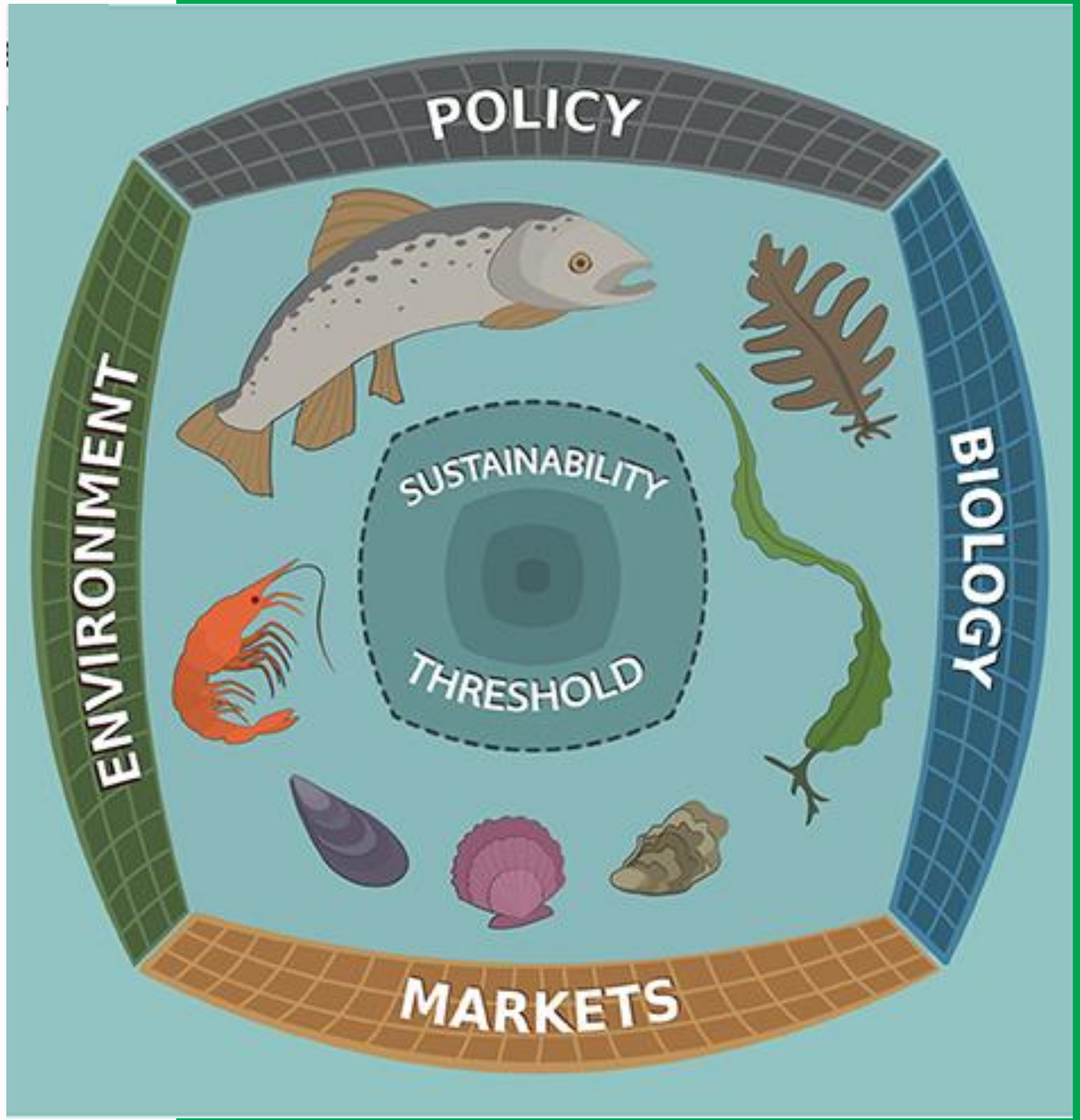

Broitman et al. (2017)

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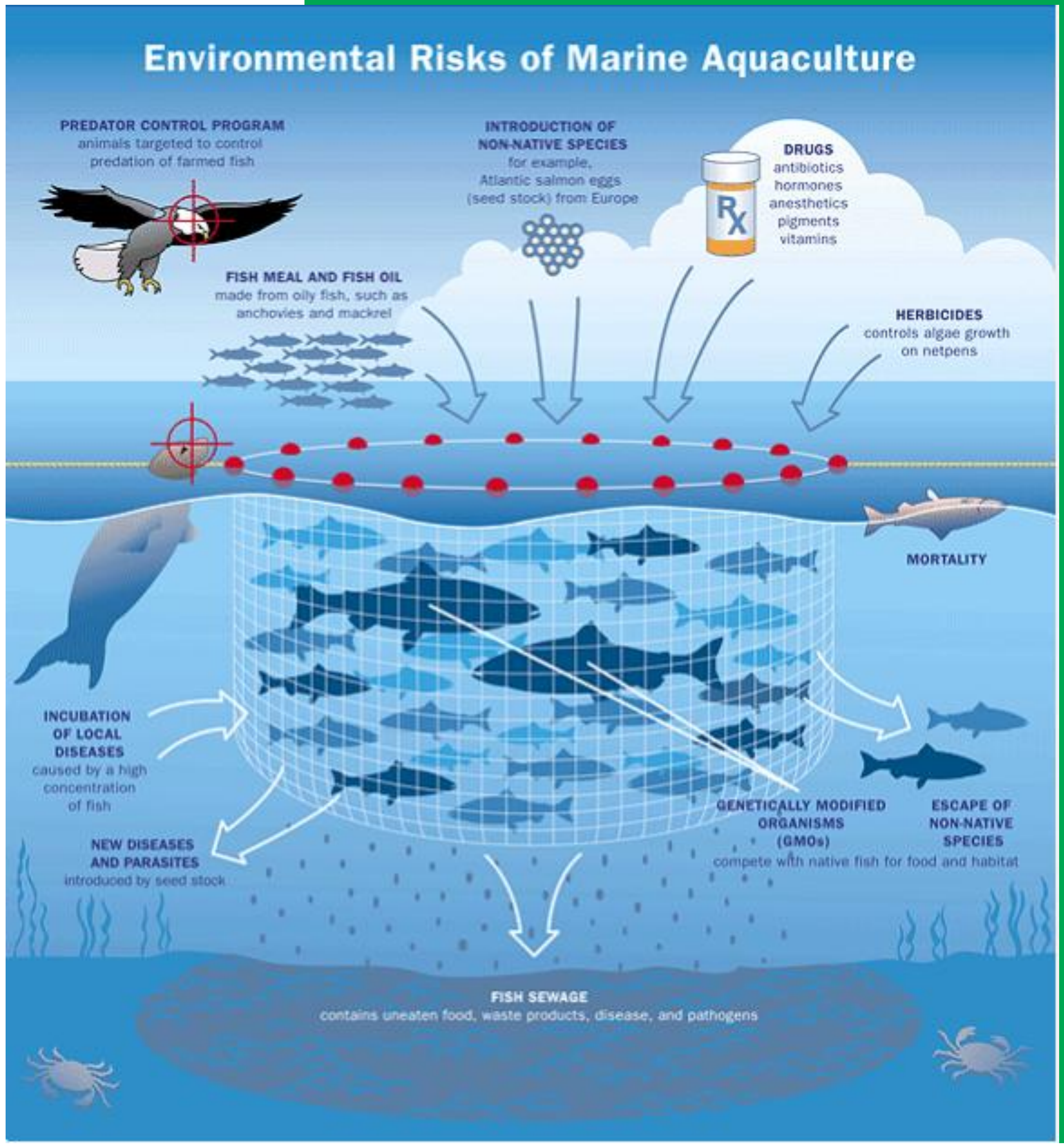
1. Environmental Pressures

- Environmental pressures in sustainable fisheries and aquaculture refer to the **external** and **internal** environmental challenges that **impact the health** of ecosystems and the long-term **viability** of fish stocks and **aquaculture operations**.
- The environmental challenges facing sustainable fisheries and aquaculture are **multifaceted**, driven by both **natural** and **anthropogenic** factors.

MAJOR PRESSURES:
1. Climate Change
2. Habitat Degradation
3. Resource Intensity and Pollution
4. Overexploitation of Resources
5. Invasive Species and Disease
6. Genetic Impacts from Escaped Farmed Fish



Some examples on environmental risks of marine aquaculture to the ecosystem
Hutchings et al. (2012) *in* Ruslan & Yusof (2021)

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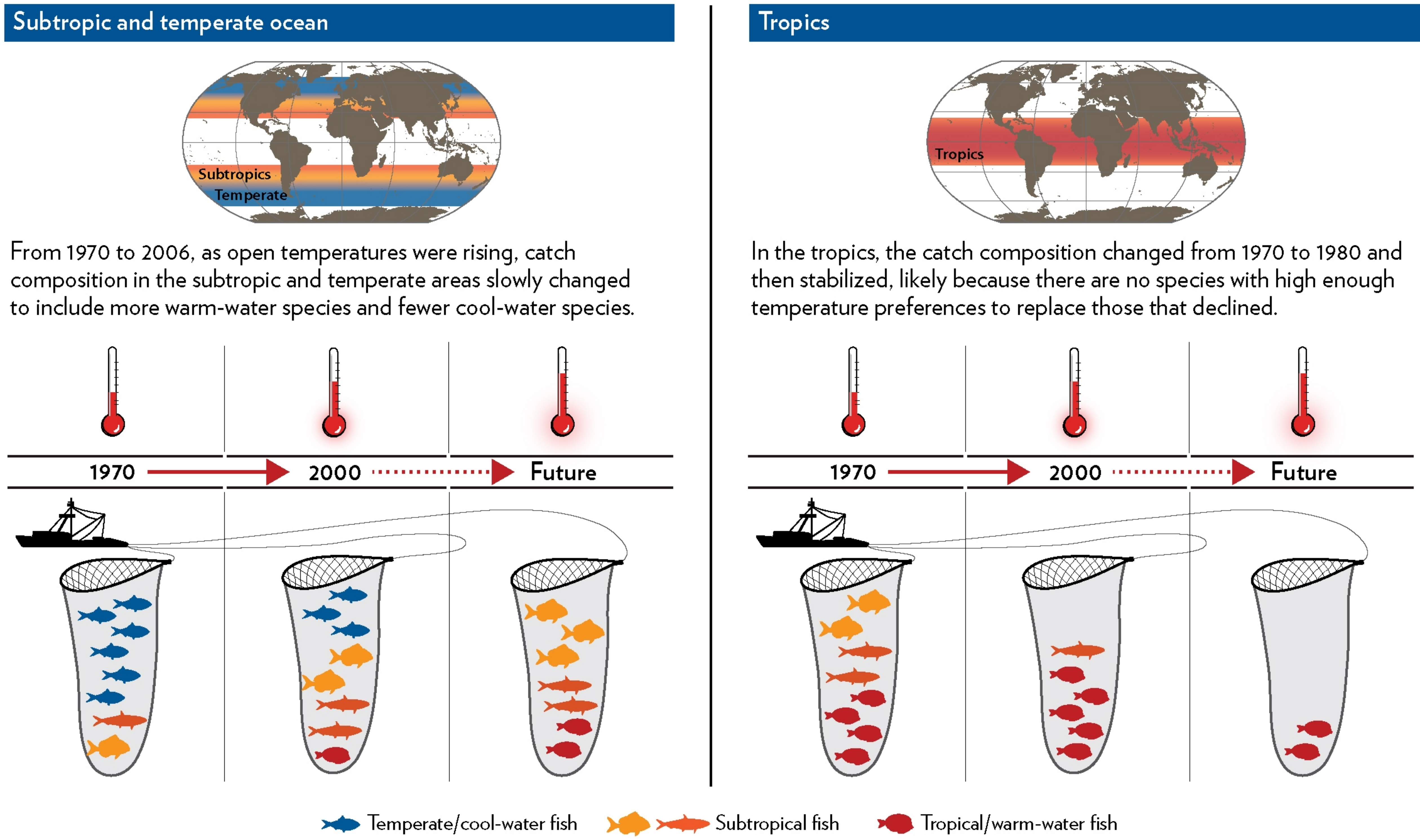
a. Climate change

- **Ocean Warming and Acidification**: Rising sea temperatures and ocean acidification disrupt marine ecosystems, affecting species distribution, reproduction, and survival. For example, coral reefs, vital for fish nurseries, are threatened by bleaching events linked to warming waters.
- **Species Migration**: Many marine species are shifting poleward at rates of ~44 miles per decade, destabilizing local fisheries and creating conflicts over resource access.
- **Extreme Weather Events**: Cyclones, floods, and droughts increasingly threaten aquaculture infrastructure and wild fish habitats, particularly in coastal regions [1].

Warming Oceans Are Reshaping Fisheries

Marine species are gradually moving away from the equator into cooler waters, and, as a result, species from warmer waters are replacing those traditionally caught in many fisheries worldwide. Scientific studies show that this change is related to increasing ocean temperatures.



These shifts could have negative effects including loss of traditional fisheries, decreases in profits and jobs, conflicts over new fisheries that emerge because of distribution shifts, food security concerns, and a large decrease in catch in the tropics.

This graphic presents concepts from: Cheung, W.W.L., R. Watson and D. Pauly. 2013. Signature of ocean warming in global fisheries catch. *Nature*. DOI:10.1038/nature12156.
The thermometers are representative of trends in ocean temperature over time and the fish are representative of trends in catch composition over time. They do not represent specific values.
Please consult the results section of Cheung *et al.* (2013) for exact data points.
Graphic by The Pew Charitable Trusts' ocean science division, www.pewenvironment.org/research-programs

seaaroundus.org

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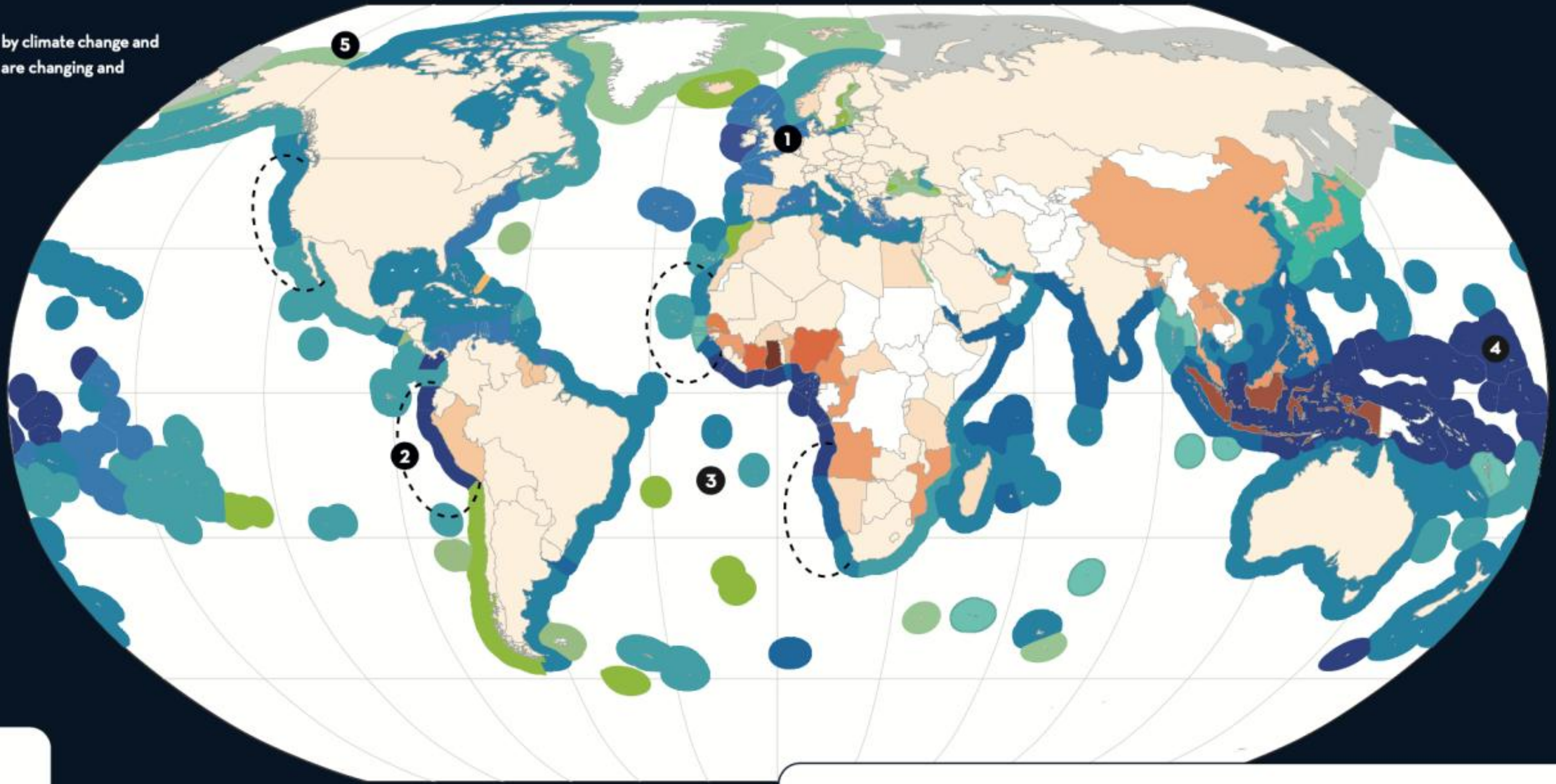
THE COMBINED IMPACTS OF CLIMATE CHANGE AND FISHING AROUND THE WORLD

On a global scale the pressures exerted by climate change and fishing on biodiversity and ecosystems are changing and vary from one region to another.



Upwelling Zones

Change (in percentage) in fishery productivity within Exclusive Economic Zones by 2100 (RCP 8.5*)

-50 | -30 | -15 | -10 | -5 | 0 | 5 | 10 | No data

*IPCC scenario where greenhouse gas concentrations continue to increase at current rates.

Current share (in percentage) of fish in animal-based diets

0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50

Climate change and fishing pressures on biodiversity and ecosystems vary across the world:

1. Semi-enclosed and continental seas host numerous human activities, whose impacts on resources are exacerbated by climate change.
2. Climate change alters currents and oxygen levels in coastal upwelling zones, affecting primary productivity and shrinking available habitats for species.
3. As coastal resources decrease, industrial high-seas fishing is expanding, targeting large predator and migratory species.
4. Rising temperatures in tropical areas are expected to lead to the largest global decline in fish catches. Small Island Developing States are particularly vulnerable, with fish resources accounting for 50% of their daily animal protein intake
5. Fishing activities are expanding towards the Arctic as glaciers are melting and the distribution range of species is shifting.

Infographics adapted from Figure 5.21 in Chapter 5 "Changing Ocean, Marine Ecosystems, and Dependent Communities" of the IPCC SROCC (2019), and from the map "Dimensions of agriculture and marine fisheries vulnerability to climate change, B. Change in fisheries productivity by 2100 (exposure; RCP8.5)," from the paper "Escaping the perfect storm of simultaneous climate change impacts on agriculture and marine fisheries" (2019).

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b. Habitat degradation

- **Mangrove Destruction**: Aquaculture expansion, especially shrimp farming, has historically led to the loss of mangrove forests, which are critical for carbon sequestration and coastal protection [2].

- **Destructive Fishing Practices**: Bottom trawling and non-selective gear damage seabed ecosystems, reducing biodiversity and disrupting food webs.

- **Destructive Fishing Practices**: Blast fishing, ghost net, poison (cyanide) fishing for ornamental fish, etc [3].

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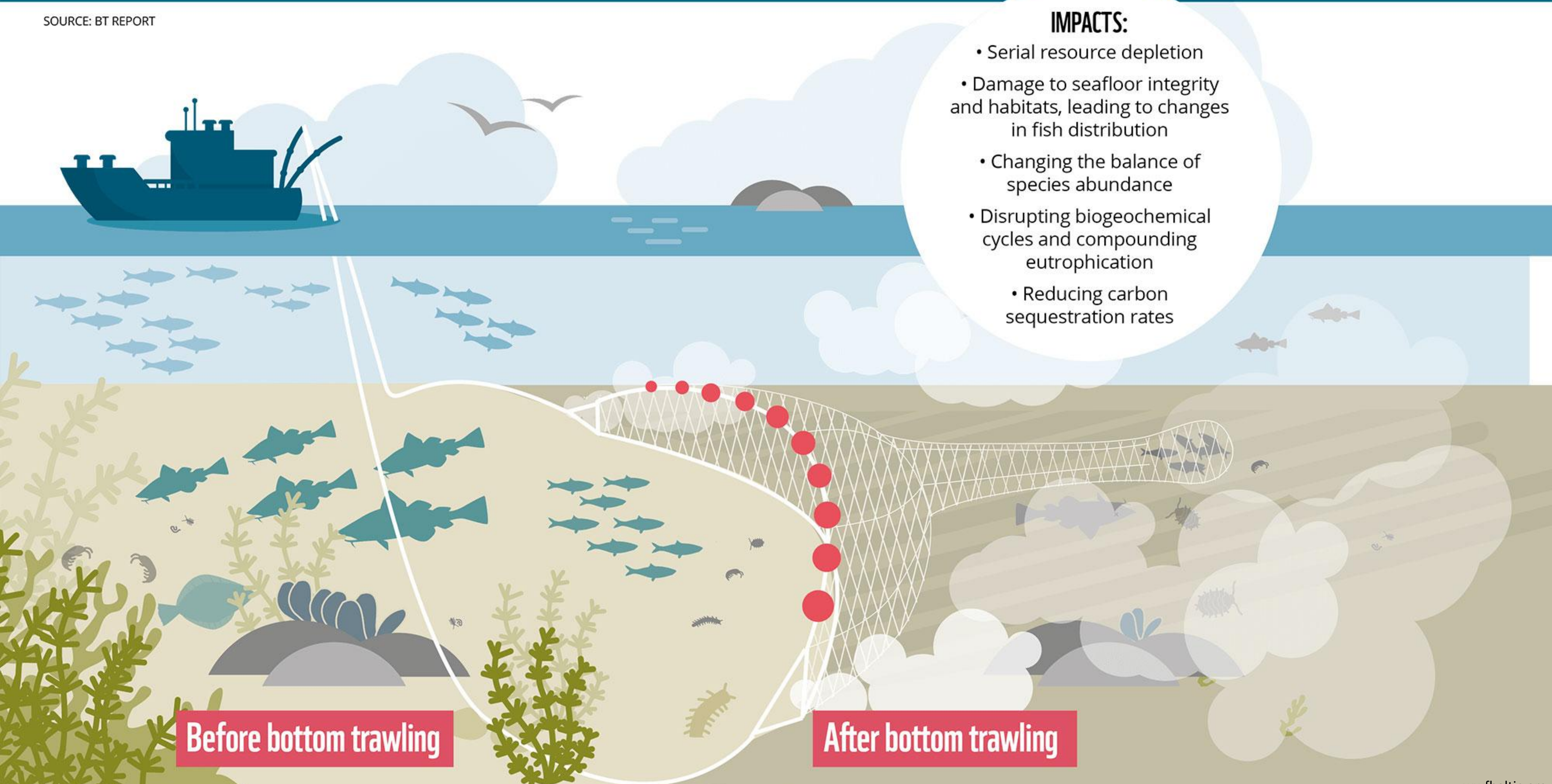
THE IMPACTS OF BOTTOM TRAWLING - BEFORE AND AFTER

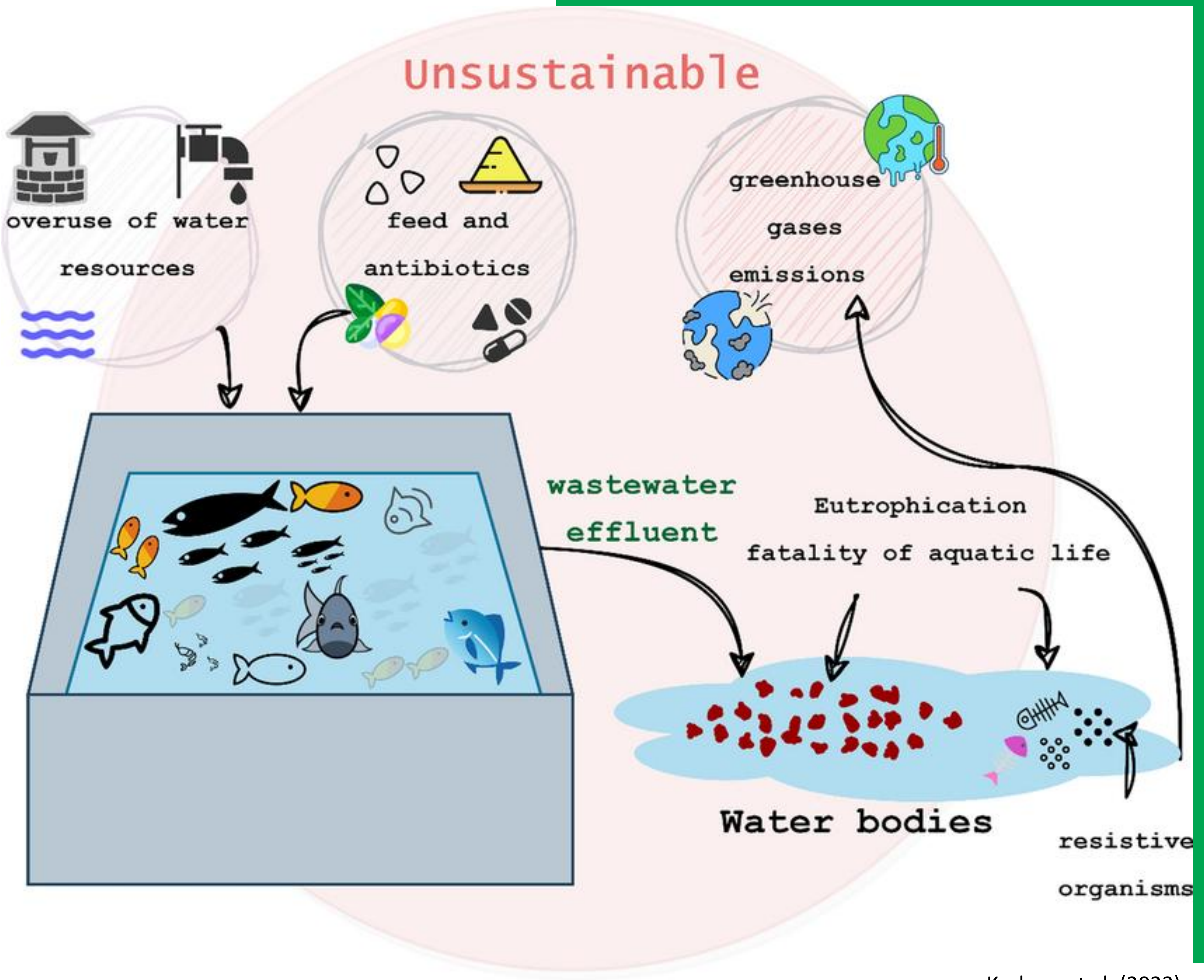
SOURCE: BT REPORT



wwfbaltic.org

c. Resource intensity & pollution

- **High Water and Energy Use**: Intensive aquaculture systems consume significant freshwater and energy, with tilapia farming in Mexico requiring 2–4 times more water than livestock production [3].
- **Greenhouse Gas Emissions**: Aquaculture contributes to climate change through feed production, energy use, and methane emissions from pond systems [1].
- Nutrient run-off from fish farms causes algal blooms, and antibiotics use risks creating drug-resistant pathogens [3].



Kashem et al. (2023)

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d. Overexploitation of resources

- **Wild Fish for Feed**: Carnivorous aquaculture species (e.g., salmon) rely on fishmeal and fish oil derived from wild-caught forage fish, exacerbating pressure on already depleted stocks [4].
- **Overfishing**: Approximately 44% of global fish stocks are fully exploited, and 16% are overfished, leading to reduced yields and biodiversity loss [5].

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e. Invasive Species and Disease

- **Pathogen Spread**: Aquaculture operations can introduce non-native species and pathogens, disrupting local ecosystems [1].
- For example, shrimp farms have been linked to viral outbreaks affecting wild populations.
- For example, introduction of Rainbow trout from Denmark to Iceland in 1950 → causing predation and competition by adults with native species especially brown trout and Arctic charr, fry and parr.


Rainbow trout - marine-freshwater.fandom.com/


Brown trout - en.wikipedia.org


Salmon infected by sea lice - courses.lsa.umich.edu

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f. Genetic impacts from escaped farmed fish

Escaped farmed fish, particularly in aquaculture-heavy regions, pose significant genetic risks to wild populations through hybridization and introgression. These impacts are well-documented in species like Atlantic salmon (*Salmo salar*), gilthead seabream (*Sparus aurata*), and European seabass (*Dicentrarchus labrax*).

- Farmed salmon in Norway, selected for growth and delayed maturation, hybridize with wild populations, leading to offspring that mature earlier and migrate to sea sooner. This disrupts local adaptations, as wild salmon are finely tuned to their natal rivers' environmental conditions.
- Hybrid offspring exhibit lower survival rates. In Norway, introgressed salmon parr (juveniles) showed 49–70% lower survival compared to wild counterparts, driven by maladaptive traits like reduced predator avoidance and competitive displacement [6].


cambaytiger.com


norwegianseafoodcouncil.com

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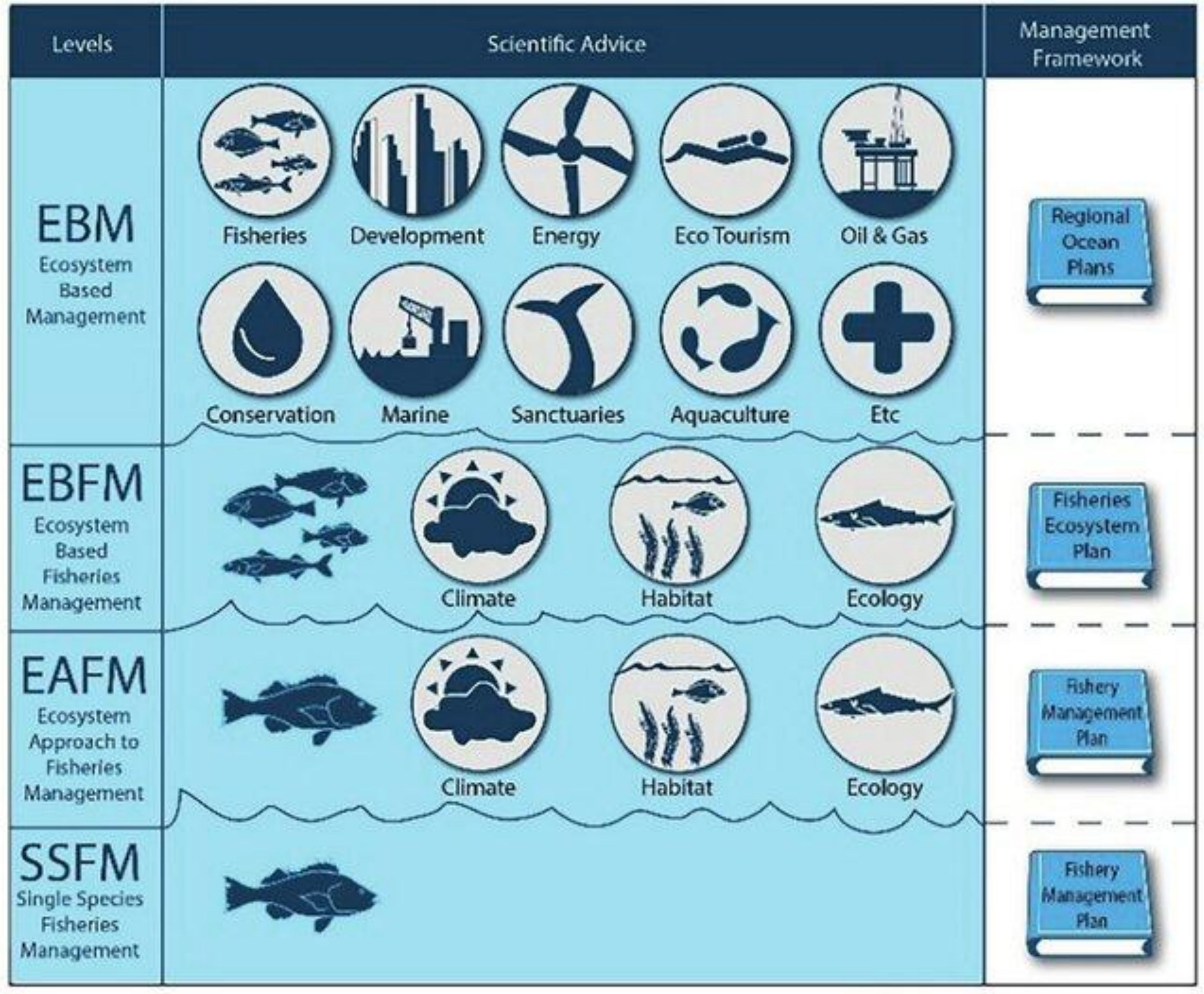
Highlight of Mitigation Strategy

a. **Ecosystem-Based Management**: Expanding marine protected areas, adopting selective fishing gear, and promoting integrated multi-trophic aquaculture (IMTA) to reduce waste and pollution.

b. **Innovative Feeds**: Transitioning to alternative protein sources (e.g., insect meal, algae) to lessen reliance on wild fish.

c. **Climate Adaptation**: Implementing recirculating aquaculture systems (RAS) and improving monitoring to address shifting fish stocks.



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2. Resource dependency & feed crises

The global expansion of aquaculture has intensified reliance on finite natural resources, particularly for feed production, creating systemic risks for both marine ecosystems and freshwater systems.

- Overreliance on Wild-Caught Fish for Feed
- Environmental Trade-offs of Alternative Feeds
- Economic and Regulatory Pressures
- Innovative Solutions to Reduce Dependency
- Socioeconomic and Food Security Implications

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a. Overreliance on Wild-Caught Fish for Feed

a. **Fishmeal and Fish Oil Dependency**: Aquaculture feeds for carnivorous species (e.g., salmon, shrimp) historically depended on **fishmeal** (FM) and **fish oil** (FO) derived from wild-caught forage fish like anchovies and herring. While FM/FO use has declined (e.g., salmon diets reduced FM from 70% in the 1980s to 25% in 2017), these ingredients remain **critical** for **omega-3 fatty acids** and **protein balance** [7].

b. **Sustainability Concerns**: Over **60% of global fish** stocks are **fully exploited** or **overfished**, and aquaculture's **demand** for FM/FO **exacerbates pressure** on pelagic fisheries. For example, 70% of FM/FO production comes from wild-caught forage fish, raising concerns about ecosystem stability and food security for communities reliant on these species

c. **Fish In: Fish Out (FIFO) Ratios**: While global aquaculture is now a net fish producer (3–4× more fish biomass produced than consumed), species like salmon still require high fish oil inputs. Economic allocation methods (eFIFO) highlight that fish oil's scarcity drives higher dependency ratios, complicating sustainability claims [8].

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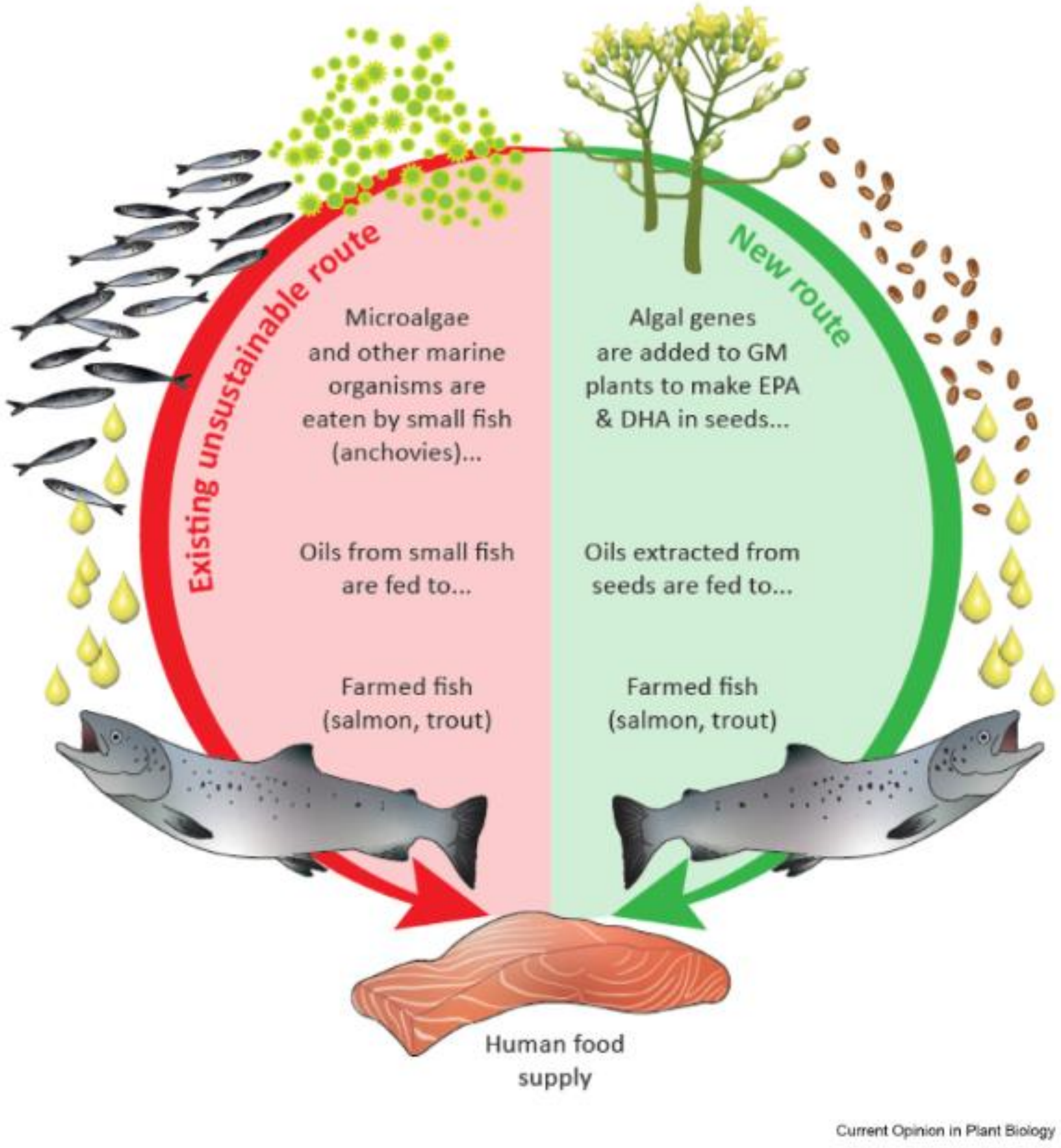
b. Environmental Trade-offs of Alternative Feeds

- **Terrestrial Crop Substitutes**: Replacing FM/FO with plant-based ingredients (e.g., soy, corn) reduces marine resource pressure but increases freshwater consumption and pollution. For instance, terrestrial alternatives raise aquaculture's water footprint by 1,629 m^3/t (green water) and 179 m^3/t (blue water), straining freshwater resources [9].

- **Deforestation and Land Use**: Soy production for aquafeed contributes to deforestation, particularly in the Amazon, and competes with food crops. ASC-certified feed standards now require traceability to ensure no illegal land conversion, but enforcement remains challenging [10].

- **Carbon Footprint**: Farmed salmon's carbon footprint (5.1 kg CO_2e/kg) slightly exceeds wild-caught salmon (4.9 kg CO_2e/kg), largely due to plant-based feed production impacts [10].



Napier & Betancor (2023)

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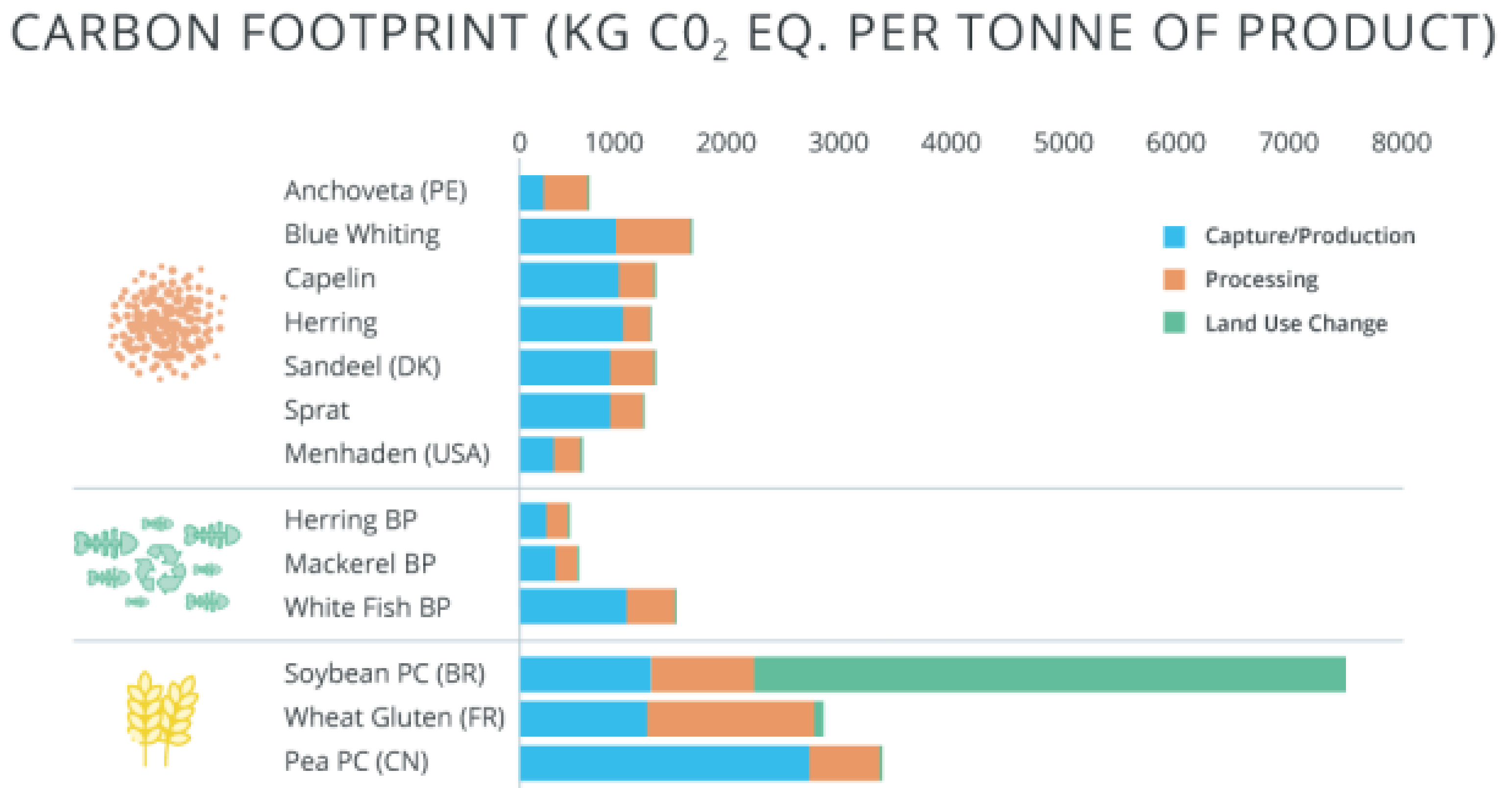
c. Economic and Regulatory Pressures

a. **Market-Driven Resource Allocation**: Rising FM/FO prices (due to limited supply and high demand) incentivize alternative ingredients. However, cost remains a barrier; insect meal, for example, costs 2–3× more than FM.

b. **Certification Standards**: The ASC Feed Standard mandates responsible sourcing of all ingredients, including marine (via Forage Fish Dependency Ratios, FFDR) and terrestrial components. FFDR calculations exclude by-products to focus on direct wild fishery impacts, promoting transparency.

c. **Policy Gaps**: Weak regulations in developing nations allow unsustainable practices, such as unmonitored mangrove conversion for shrimp farms or unchecked feed crop expansion [11].



Source: based on data provided by Dr Richard Newton. University of Stirling, UK

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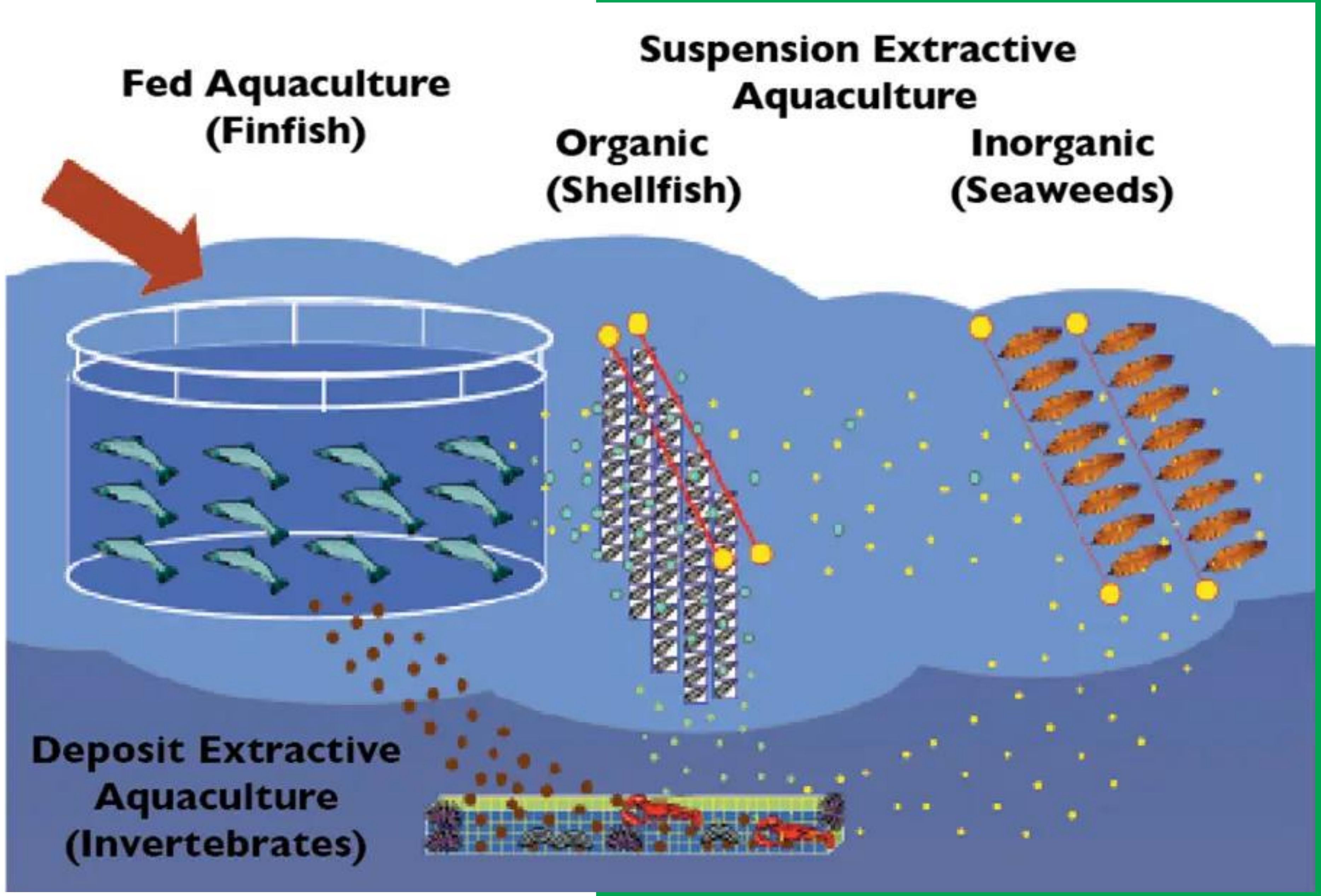
d. Innovative Solutions to Reduce Dependency

- **Insect Protein**: Black Soldier Fly (BSF) larvae convert organic waste into high-protein meal (50–80% protein content). Studies show BSF-fed fish exhibit improved growth and immunity, though scaling production remains a hurdle due to high costs (~€2,500–4,000/ton) [12].
- **Algae and Microbial Oils**: Algae-derived oils replicate fish oil's omega-3 benefits without marine inputs. Companies like Cargill and Biomar are integrating these into feeds, though production scalability is limited.
- **Circular Systems**: Integrated multi-trophic aquaculture (IMTA) uses filter feeders (e.g., mussels, seaweed) to recycle waste from finfish farms, reducing nutrient pollution and improving resource efficiency [13].



globalseafood.org

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e. Socioeconomic and Food Security Implications

a. **Competition for Resources**: Small pelagic fish used for FM/FO are also vital for direct human consumption in regions like West Africa. Aquaculture’s demand risks diverting these resources, exacerbating food insecurity [10].

b. **Employment Vulnerabilities**: Over 36 million people depend on fisheries and aquaculture for livelihoods. Feed crises threaten small-scale farmers who lack access to sustainable alternatives [11].

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Pathways to Sustainability

a. **Ecosystem-Based Feed Formulations**: Prioritize ingredients with low water and land footprints, such as algae or insect meal, while maintaining nutrient profiles.

b. **Policy Harmonization**: Enforce global standards like ASC's FFDR metrics and incentivize FM/FO alternatives through subsidies or tax breaks.

c. **Technological Investment**: Scale insect farming via decoupled production models (separating breeding and rearing) and proximity to waste streams to reduce costs.

d. **Consumer Awareness**: Promote certified sustainable seafood to drive market demand for responsibly sourced feeds.

CONCLUSION

Resource dependency in aquaculture underscores a delicate balance between meeting global protein demand and preserving ecosystems. While innovations like insect protein and IMTA offer promise, systemic change requires coordinated efforts across policy, industry, and consumer behavior. Reducing reliance on wild-caught fish and mitigating terrestrial feed impacts will be critical to achieving a sustainable "blue transformation".

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3. Economic & Market Instability

The fisheries and aquaculture sector faces significant economic and market instability driven by geopolitical tensions, fluctuating demand, production challenges, and regulatory uncertainties.

CRITICAL FACTORS:

1. Geopolitical Tensions and Trade Risks
2. Production Costs and Feed Price Volatility
3. Demand-Side Pressures
4. Biological and Environmental Challenges
5. Regulatory and Policy Risks
6. Technological and Operational Innovations

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a. Geopolitical Tensions and Trade Risks

- **Tariffs and Trade Restrictions**: The potential imposition of new U.S. tariffs under the incoming administration, particularly targeting China (the world's largest seafood producer and exporter), threatens to disrupt global seafood trade. The U.S. relies on imports for over 80% of its seafood consumption, making it highly vulnerable to such policies [13].
- **Market Access Uncertainty**: Geopolitical conflicts, such as the Russia-Ukraine war, continue to strain supply chains and inflate costs for fuel, transportation, and feed ingredients.

Country	Tariffs Charged to the U.S.A. Including Currency Manipulation and Trade Barriers	U.S.A. Discounted Reciprocal Tariffs
Peru	10%	10%
Ecuador	12%	10%
Norway	30%	15%
Costa Rica	17%	10%
Jordan	40%	20%
India	52%	26%
United Arab Emirates	10%	10%
New Zealand	20%	10%
Argentina	10%	10%
Indonesia	64%	32%
Guatemala	10%	10%
Honduras	10%	10%
Madagascar	93%	47%

b. Production Costs and Feed Price Volatility

- **Feed Dependency**: Feed accounts for up to 70% of aquaculture operating costs. Fluctuations in prices for fishmeal, soy, and corn, compounded by climate disruptions and geopolitical instability, directly impact profitability.
- **Regional Feed Production Disparities**: Europe's aquaculture feed production grew by 2.1% in 2024 due to sustainable practices and technological advances, while Asia-Pacific and the Americas saw declines (-1.7% and -3.7%, respectively) due to disease outbreaks and economic instability [14].

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c. Demand-Side Pressures

- **Weak Consumer Spending**: Inflation and economic uncertainty have led to restrained demand in major markets like the EU and U.S., with consumers prioritizing lower-priced seafood products. Shrimp prices remain depressed due to oversupply, particularly in China, where import volumes have declined monthly since February 2024 [13].
- **Shifting Consumer Preferences**: Gen Z's demand for "better-for-you" products and transparency in sourcing practices pressures producers to adopt sustainable and traceable practices, increasing operational costs.

d. Biological & Environmental Challenges

- **Disease Outbreaks**: High mortality rates due to diseases like Salmon Rickettsial Syndrome (SRS) in Chile and sea lice in Norway disrupt production. For example, Norway's salmon growth was limited to 1–2% in 2024 due to biological challenges.
- **Regional Feed Production Disparities**: Extreme weather events (e.g., El Niño-induced algae blooms in Chile) and warming waters force early harvesting and reduce biomass, destabilizing supply.

salmonwatchireland.ie

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e. Regulatory and Policy Risks

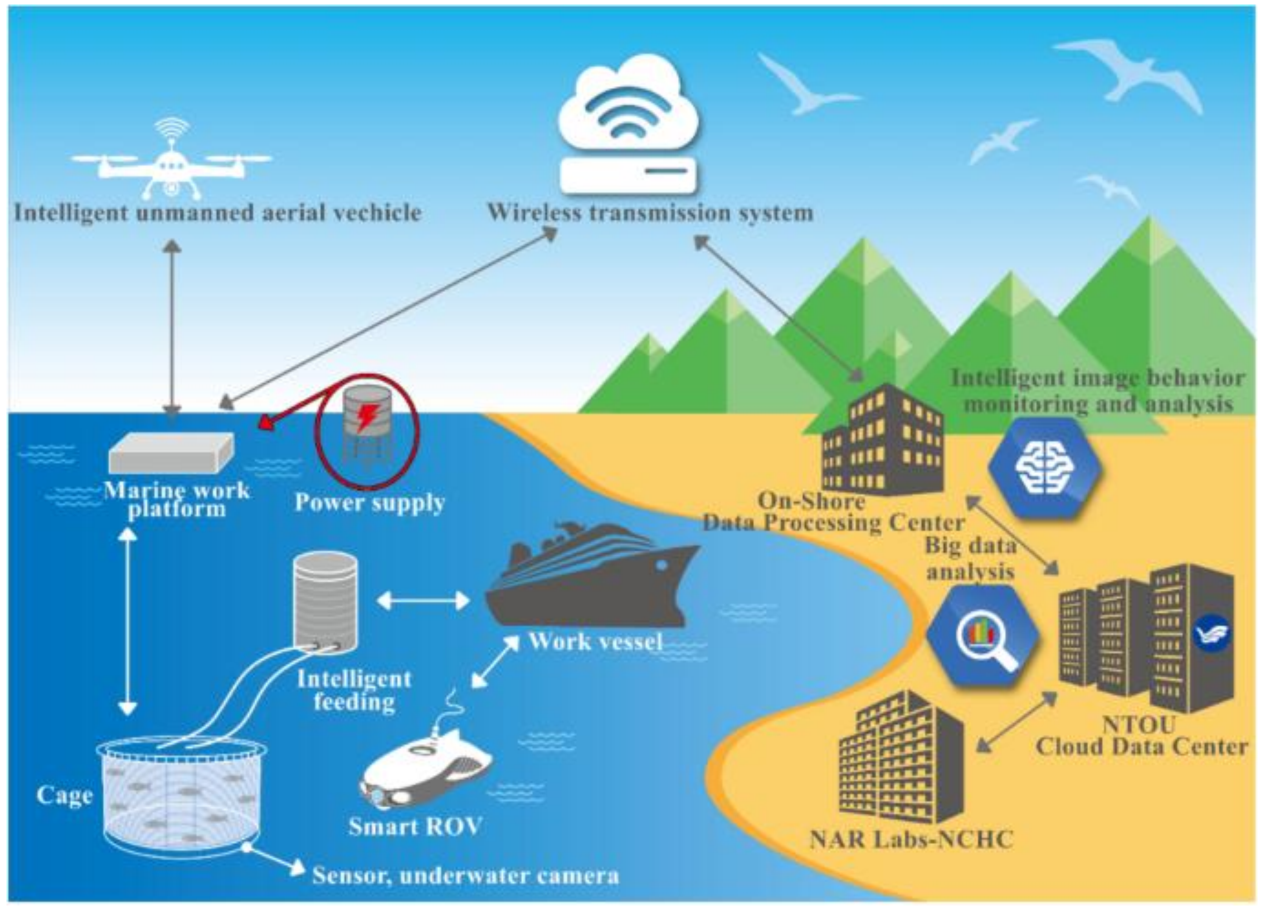
- **Harmful Subsidies**: The OECD reports that 65% of global fisheries subsidies risk encouraging overfishing and illegal practices, particularly in regions with weak management systems [15].

- **Legislative Delays**: The U.S. Farm Bill, critical for expanding USDA support to seafood producers (e.g., access to credit, "Buy American" labeling), faces delays, leaving $31 billion in disaster relief funds uncertain for aquaculture.

f. Technological and Operational Innovations

- **AI and Automation**: Adoption of AI for monitoring fish health, optimizing feeding, and reducing waste (e.g., South Africa's AquaBrain Net) improves efficiency but requires upfront investment.

- **Recirculating Aquaculture Systems (RAS)**: RAS technology reduces water use by 95% and mitigates environmental risks, though high capital costs limit widespread adoption.



Chang et al. (2021)

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Mitigation Strategies and Opportunities

a. Diversification and Resilience:
- Expand species with stable demand, such as pangasius (+7% growth) and tilapia (+5%), which are less reliant on volatile markets.
- Invest in circular economies, e.g., using fish processing waste for feed to reduce costs and improve sustainability.

b. Policy Alignment:
- Advocate for reforms to redirect subsidies toward stock assessments, enforcement, and climate adaptation.

c. Market Adaptation:
- Enhance traceability and certification (e.g., MSC or ASC standards) to meet consumer demands for sustainability.

CONCLUSION

Economic and market instability in fisheries and aquaculture stems from a complex interplay of geopolitical, environmental, and regulatory factors. While challenges like trade wars, feed costs, and disease outbreaks persist, innovations in technology, policy reforms, and strategic market diversification offer pathways to resilience. Stakeholders must prioritize collaboration across supply chains, advocate for balanced subsidies, and adopt adaptive practices to navigate this volatile landscape.

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4. Social & Ethical Concerns

The fisheries and aquaculture sectors face significant social and ethical challenges, ranging from labor exploitation to cultural displacement. These issues intersect with environmental sustainability and economic equity, requiring systemic reforms.

CRITICAL CONCERNS:

1. Labor Exploitation and Human Rights Abuses
2. Inequitable Resource Access
3. Ethical Concerns in Production Practices
4. Cultural and Community Displacement
5. Food Security and Equity
6. Certification and Greenwashing

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a. Labor Exploitation and Human Rights Abuses

- **Forced Labor and Modern Slavery**: Industrial fishing fleets, particularly in regions like Southeast Asia, are notorious for coercive labor practices. Migrant workers often face debt bondage, withheld wages, and hazardous conditions. The 2023 U.S. Department of Labor Report identified seafood as a high-risk sector for forced labor.

- **Child Labor**: Small-scale fisheries in developing nations (e.g., West Africa) employ children in dangerous tasks like diving or net repair, depriving them of education and exposing them to injury.

b. Inequitable Resource Access

- **Marginalization of Small-Scale Fishers**: Industrial fleets and aquaculture operations often displace artisanal fishers, who contribute ~50% of global fish catches and employ 90% of workers in the sector. In India, shrimp farms have encroached on traditional fishing grounds, sparking conflicts.

- **Gender Inequality**: Women, who represent 50% of the workforce in post-harvest roles (e.g., processing, marketing), face wage gaps, limited decision-making power, and unsafe working conditions. In Ghana, women fish processors earn 30% less than male counterparts.

13 suspected foreign fishing vessels where 34 Indonesian migrant fishers have reported conditions which suggest signs of forced labour. Four main complaints have been identified: deception involving 11 foreign fishing vessels; withholding of wages involving 9 foreign fishing vessels; excessive overtime involving 8 foreign fishing vessels; physical and sexual abuse involving 7 foreign fishing vessels
– **Greenpeace** & **SBMI**

greenpeace.org

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c. Ethical Concerns in Production Practices

- **Bycatch and Animal Welfare**: Non-selective fishing gear (e.g., trawls, gillnets) kills millions of non-target species annually, including endangered turtles and seabirds. In aquaculture, overcrowded conditions (e.g., salmon cages) cause stress, disease, and high mortality rates, raising ethical questions about animal treatment.

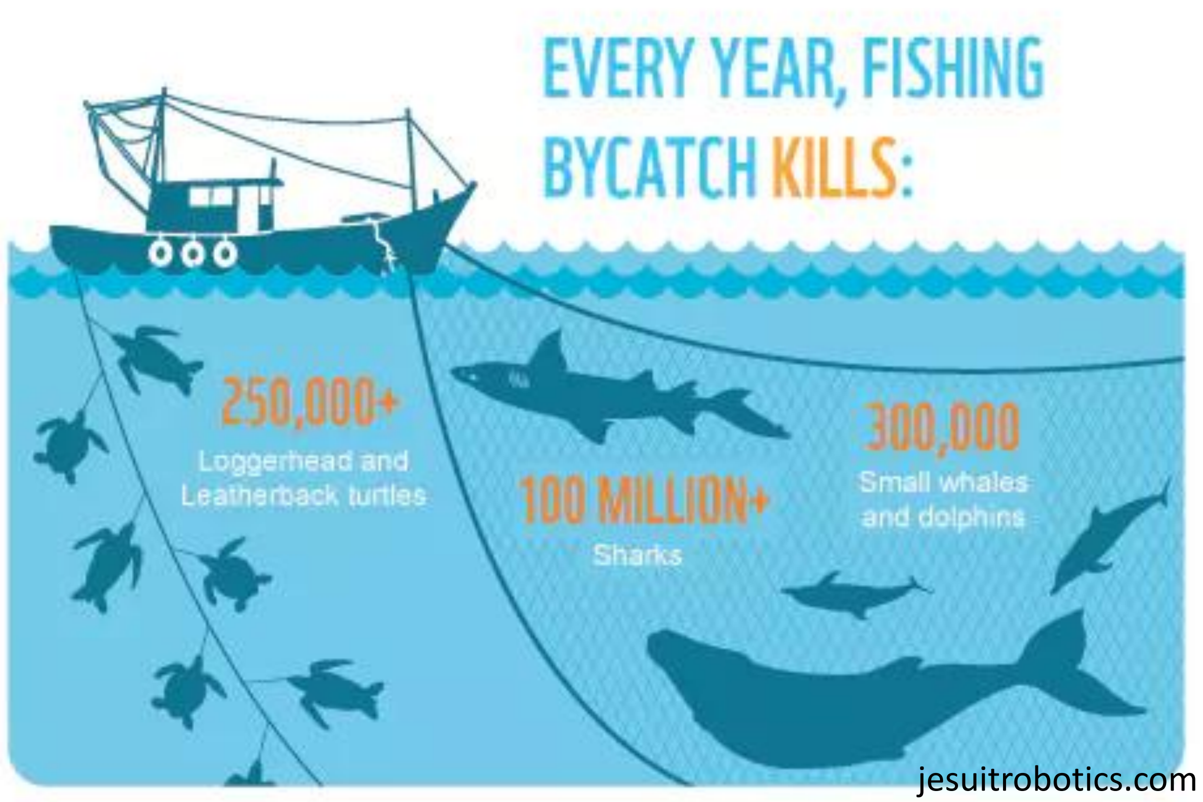
- **Antibiotic overuse**: To prevent disease in intensive aquaculture, antibiotics like oxytetracycline are overused, contributing to antimicrobial resistance (AMR). In Vietnam, 75% of shrimp farms exceed recommended antibiotic doses.

d. Cultural and Community Displacement

- **Loss of Indigenous Practices**: Industrial fishing and aquaculture projects often disregard traditional knowledge and tenure systems. In Canada, salmon farming on Indigenous territories has disrupted cultural practices and food sovereignty.

- **Coastal Community Dispossession**: Large-scale aquaculture (e.g., Ecuadorian shrimp farms) frequently converts mangroves and wetlands, displacing communities reliant on these ecosystems for livelihoods and storm protection.

indigenousfoundations.arts.ubc.ca



jesuitrobotics.com

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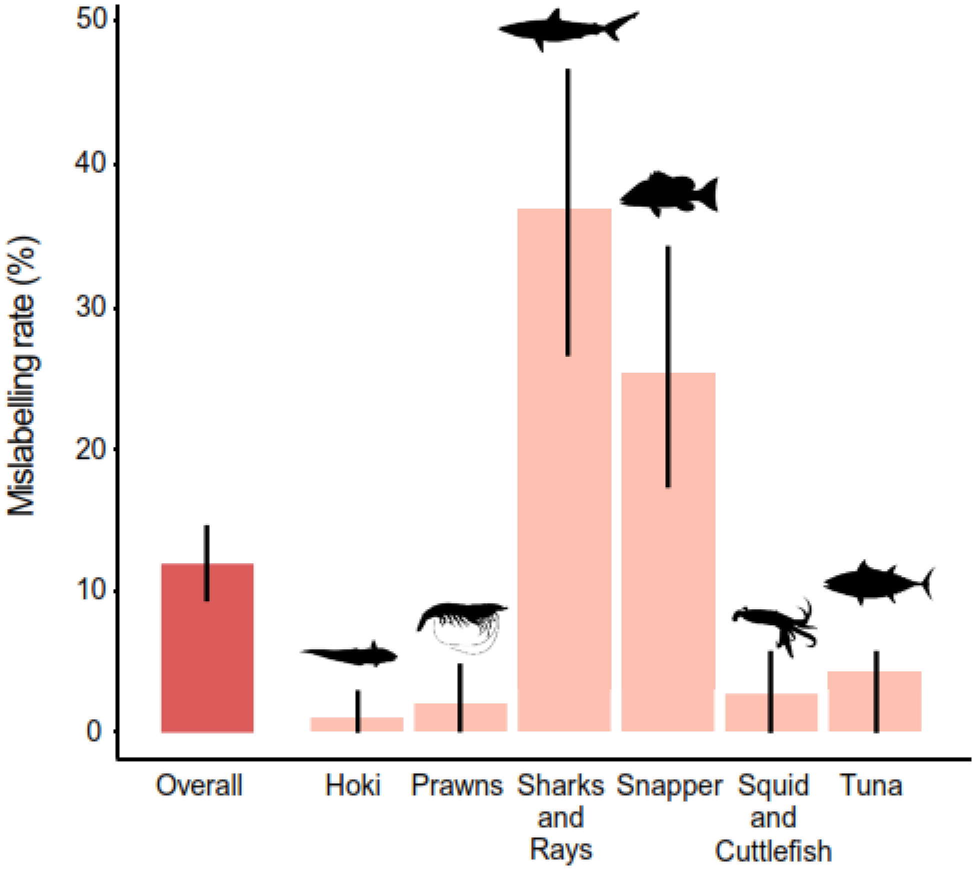
e. Food Security and Equity

- **Overfishing and Local Food Access**: Export-oriented fisheries deprive coastal communities of protein sources. In West Africa, 30–50% of fish catches are diverted to foreign markets or fishmeal production, exacerbating malnutrition.
- **Corporate Consolidation**: Vertical integration in aquaculture (e.g., Norwegian salmon firms controlling 70% of global production) concentrates profits, marginalizing smallholders and inflating consumer prices.

f. Certification and Greenwashing

- **Exclusionary Standards**: Certification schemes like MSC (Marine Stewardship Council) or ASC (Aquaculture Stewardship Council) often exclude small-scale fishers due to high costs and bureaucratic hurdles. Only 15% of global fisheries are certified, primarily industrial operations.
- **Mislabeling and Fraud**: Up to 30% of seafood is mislabeled, masking illegal catches or unethical practices. For example, "organic" shrimp farms in Southeast Asia have been linked to mangrove destruction and labor abuses.



Seafood mislabelling rates overall and by seafood group in Australia as the percentage of labels that did not match the species identified by the DNA genomic analysis

Cundy et al., 2023

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Mitigation Strategies (1)

a. Strengthen Labor Rights:
- Enforce the ILO Work in Fishing Convention (C188) to protect fishers' rights.
- Partner with NGOs like the Environmental Justice Foundation to monitor supply chains.

b. Empower Small-Scale Actors:
- Implement community-based fisheries management (e.g., Territorial Use Rights in Fisheries, TURFs) to secure resource access.
- Provide subsidies for smallholders to adopt sustainable practices and access certifications.

c. Ethical Production Reforms:
- Phase out destructive gear (e.g., bottom trawling) and mandate bycatch reduction devices.
- Promote integrated multi-trophic aquaculture (IMTA) to improve animal welfare and reduce waste.

d. Transparency and Traceability:
- Adopt blockchain or DNA barcoding (e.g., TRUfish) to verify sourcing and combat fraud.
- Mandate human rights due diligence in corporate supply chains under frameworks like the EU Corporate Sustainability Due Diligence Directive.

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Mitigation Strategies (2)

e. Cultural and Equity Frameworks:

- Recognize Indigenous rights through co-management agreements (e.g., Canada's Namgis First Nation salmon stewardship).
- Prioritize local food security in trade policies, reserving a percentage of catches for domestic markets.

CONCLUSION

Social and ethical concerns in fisheries and aquaculture are deeply intertwined with environmental and economic sustainability. Addressing these issues requires prioritizing human rights, equitable resource distribution, and cultural preservation alongside ecological stewardship. Governments, corporations, and consumers must collaborate to dismantle exploitative systems and foster a just transition toward ethical seafood production. As highlighted by the FAO's Blue Transformation agenda, sustainability cannot be achieved without social equity at its core.

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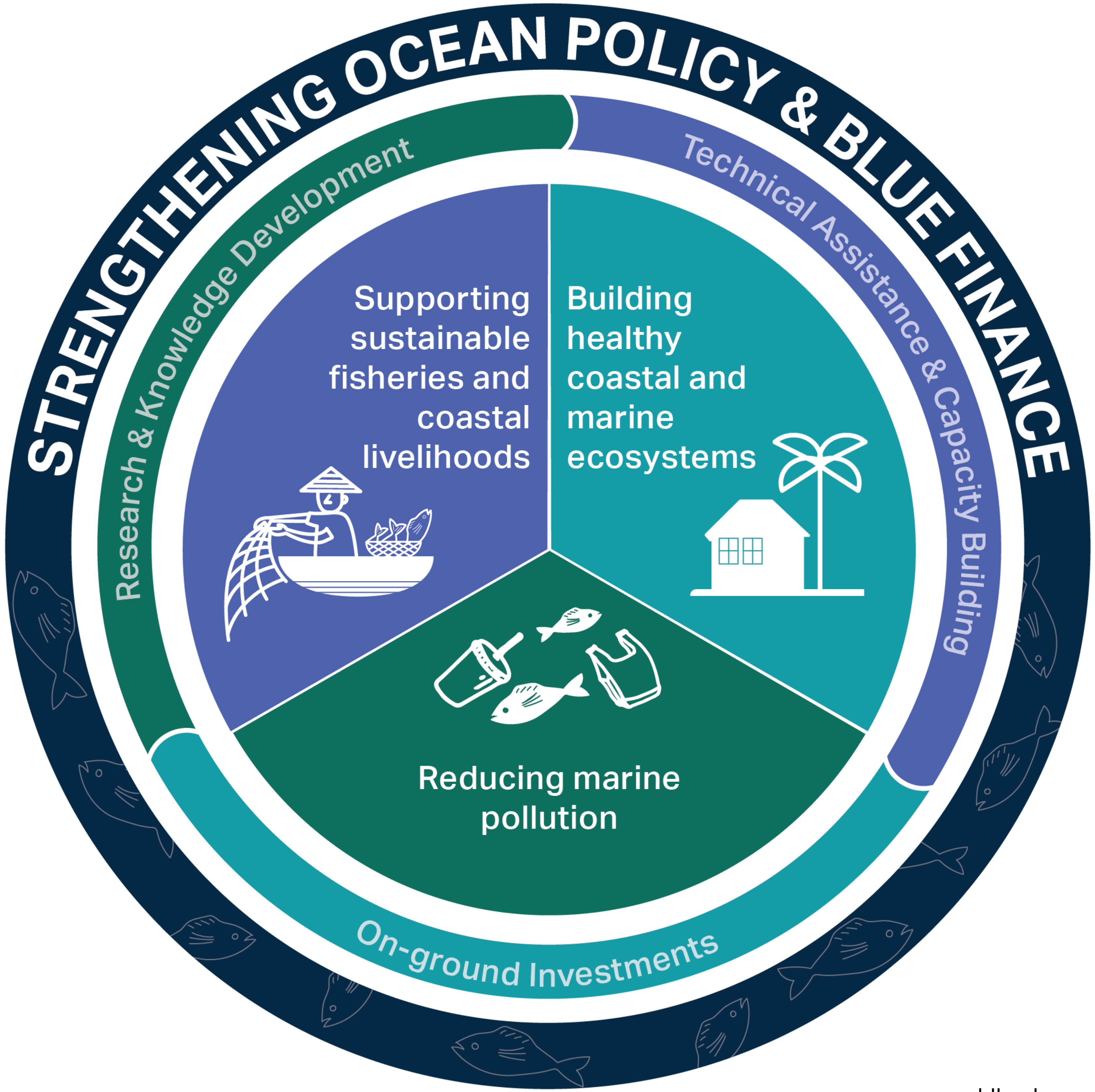
5. Governance & policy gaps*

Indonesia's fisheries and aquaculture sectors are critical to its economy, food security, and coastal livelihoods. However, systemic governance challenges and policy gaps threaten sustainability, equity, and long-term viability.

KEY ISSUES:
1. Ineffective Regulatory Frameworks
2. Weak Enforcement and IUU Fishing
3. Inequitable Resource Allocation
4. Aquaculture-Specific Challenges
5. Climate and Biodiversity Misalignment
6. Global Governance and Market Pressures



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a. Ineffective Regulatory Frameworks

- **Overcapacity and Overfishing**: Despite policies aimed at limiting fishing effort, Indonesia's waters remain overcrowded, with 90% of fishing vessels operating in overexploited zones. **Quota-based systems**, effective in countries like New Zealand, have seen **limited adoption** due to **institutional constraints** and **dominance of small-scale fisheries**, which **complicate monitoring and enforcement** [16].
- **Aquaculture Zoning Failures**: **Unregulated shrimp farm** expansion has destroyed 20–50% of mangroves in regions like Ecuador and Bangladesh, violating international commitments such as the Ramsar Convention [16]. In Indonesia, similar patterns threaten coastal ecosystems, despite recent efforts to prioritize sustainable practices under the "blue economy" framework.

Indonesia is implementing a quota-based fisheries management system to ensure sustainable and optimal utilization of fish resources. This system, known as Measured Fishery Catch (PIT) or Quota-Based Fishing, sets catch quotas for different fishing sectors and areas. The goal is to prevent overfishing and protect the marine ecosystem while promoting the fishing industry and exports

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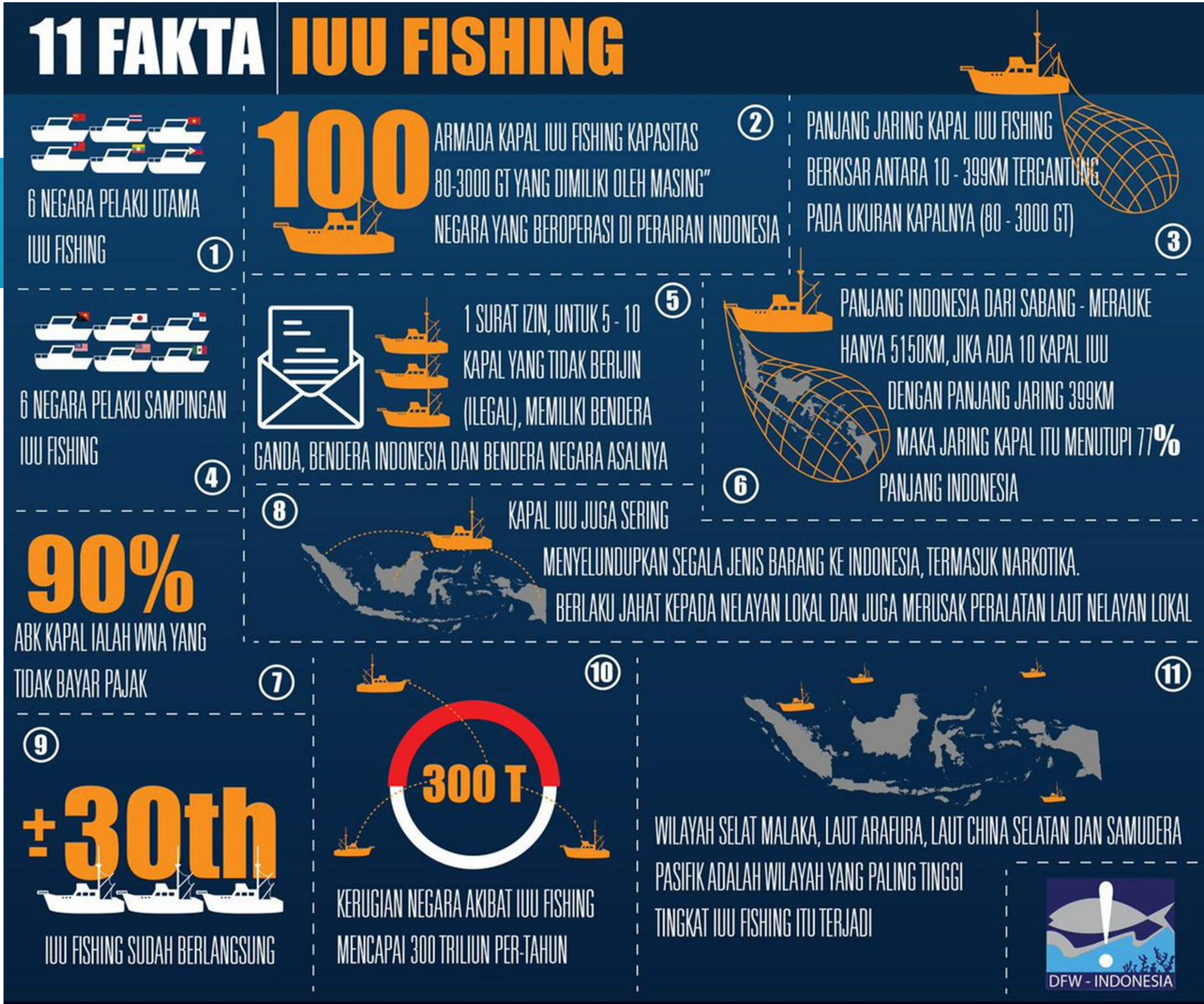
b. Weak Enforcement and IUU Fishing

- **Illegal Puerulus Trade**: Smuggling of juvenile lobsters (puerulus) persists despite export bans, driven by high demand in Vietnam and corruption. This illegal trade costs Indonesia ~$90 million annually in economic losses and undermines domestic aquaculture growth [17].
- **Inadequate Monitoring**: Only 30% of countries publish accessible fisheries data, and Indonesia struggles with IUU fishing due to limited surveillance capacity. For example, 40% of Chinese distant-water fleets in Indonesian waters operate without mandatory tracking systems [17].



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c. Inequitable Resource Allocation

- **Marginalization of Small-Scale Fishers**: Small-scale fishers, who contribute ~50% of catches, often lack legal rights to fishing grounds. Industrial fleets and aquaculture concessions (e.g., 92% controlled by five firms in Chile) dominate, exacerbating social inequality [16].

- **Harmful Subsidies**: Over $500 million in annual subsidies primarily benefit industrial fleets, incentivizing overfishing. Only one-third of subsidies support sustainable practices, such as marine protected areas like Raja Ampat.

d. Aquaculture-Specific Challenges

- **Disease and Antibiotic Overuse**: Small-scale fishers, who contribute ~50% of catches, often lack legal rights to fishing grounds. Industrial fleets and aquaculture concessions (e.g., 92% controlled by five firms in Chile) dominate, exacerbating social inequality.
- **Technology and Infrastructure Gaps**: Over $500 million in annual subsidies primarily benefit industrial fleets, incentivizing overfishing. Only one-third of subsidies support sustainable practices, such as marine protected areas like Raja Ampat.
- **Seaweed Sector Limitations**: Seasonal production, poor infrastructure, and lack of commercial hatcheries hinder Indonesia's potential as a global leader. Policy gaps in research funding and cultivar development persist [18].

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e. Climate and Biodiversity Misalignment

- **Lack of Adaptive Management**: **Fisheries policies** often **ignore climate impacts**, such as warming-driven stock shifts. For example, Indonesia's lobster puerulus survival rates are threatened by warming waters, yet policies focus on export bans rather than ecosystem resilience [17].
- **Biodiversity Blind Spots**: Certification schemes like ASC neglect cumulative impacts. Salmon farming in Norway reduced local cod populations by 45% through sea lice infestations—a risk mirrored in Indonesian aquaculture [16].

f. Global Governance and Market Pressures

- **WTO Subsidy Deadlocks**: The 2022 WTO agreement failed to curb harmful subsidies, exempting 80% of global fleets. Indonesia's reliance on exports (e.g., shrimp to the U.S. and EU) exposes it to trade barriers, such as FDA refusals for "short-weighted" shipments.
- **Certification Exclusion**: Small-scale producers struggle with costly certifications like MSC/ASC, limiting market access. Only 15% of global fisheries are certified, favoring industrial operators [Suherman].

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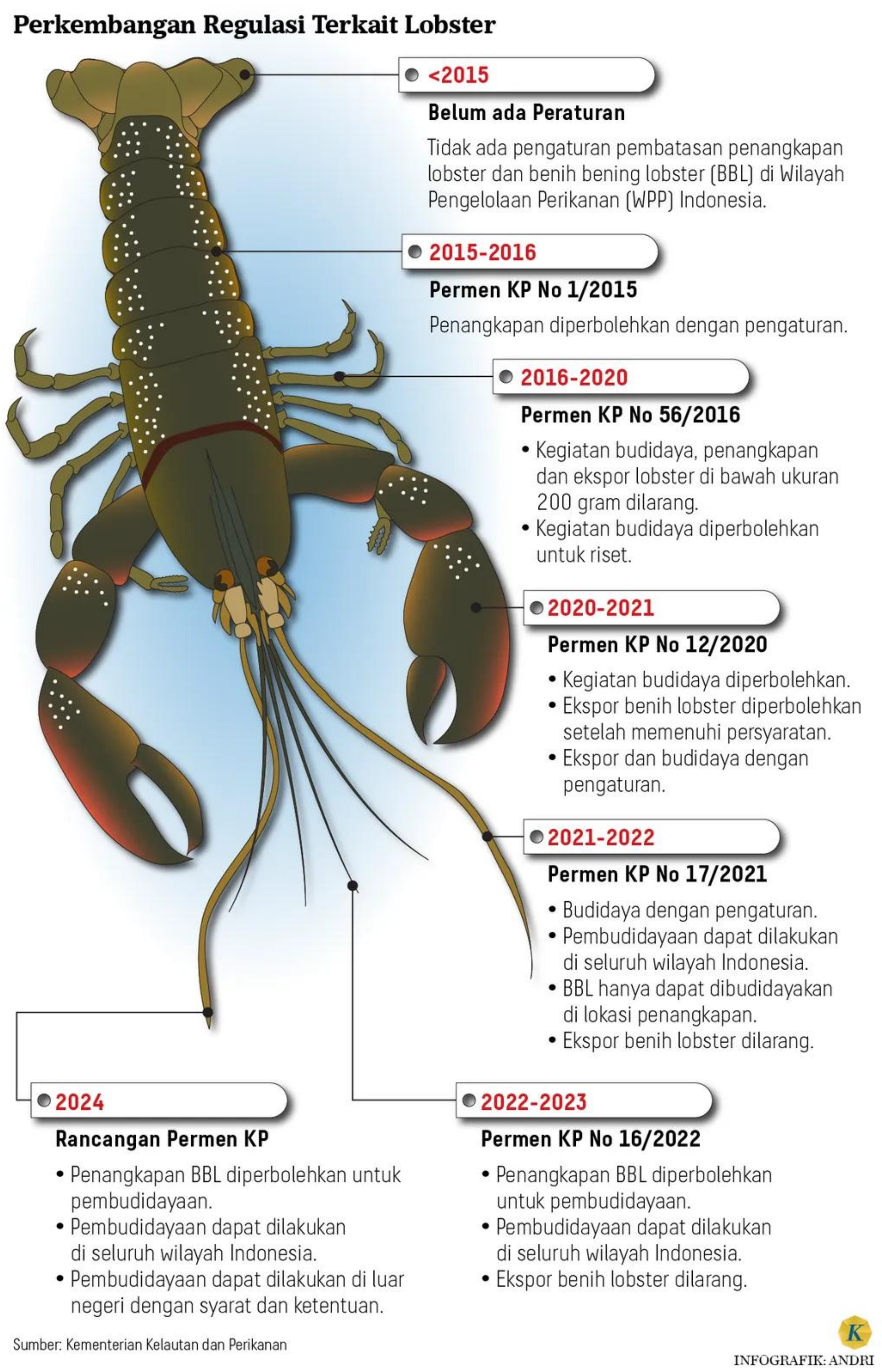

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Pathways to Reforms

a. **Strengthen Co-Management**: Adopt adaptive governance models, as seen in Malawi and Uganda, integrating local knowledge and scientific data for responsive policymaking.
b. **Tech-Driven Transparency**: Implement blockchain traceability and AI monitoring (e.g., FishFace) to combat IUU fishing and improve compliance.
c. **Equitable Subsidy Reforms**: Redirect funds to support small-scale fishers and sustainable practices, such as Raja Ampat's marine protected areas.
d. **Aquaculture Innovation**: Scale integrated multi-trophic systems (IMTA) and insect-based feeds to reduce wild fish dependency.
e. **Global Collaboration**: Align policies with SDGs and regional agreements (e.g., ASEAN) to harmonize standards and combat transboundary issues like puerulus smuggling.

CONCLUSION

Indonesia's governance gaps in fisheries and aquaculture stem from fragmented policies, enforcement deficits, and inequitable resource distribution. While initiatives like the 2025 sustainable fishing target and Shrimp Outlook 2025's focus on biosecurity signal progress, systemic reforms—prioritizing transparency, equity, and climate resilience—are critical. By leveraging technology, co-management, and global partnerships, Indonesia can transition from resource exploitation to sustainable stewardship, ensuring long-term food security and ecological health.

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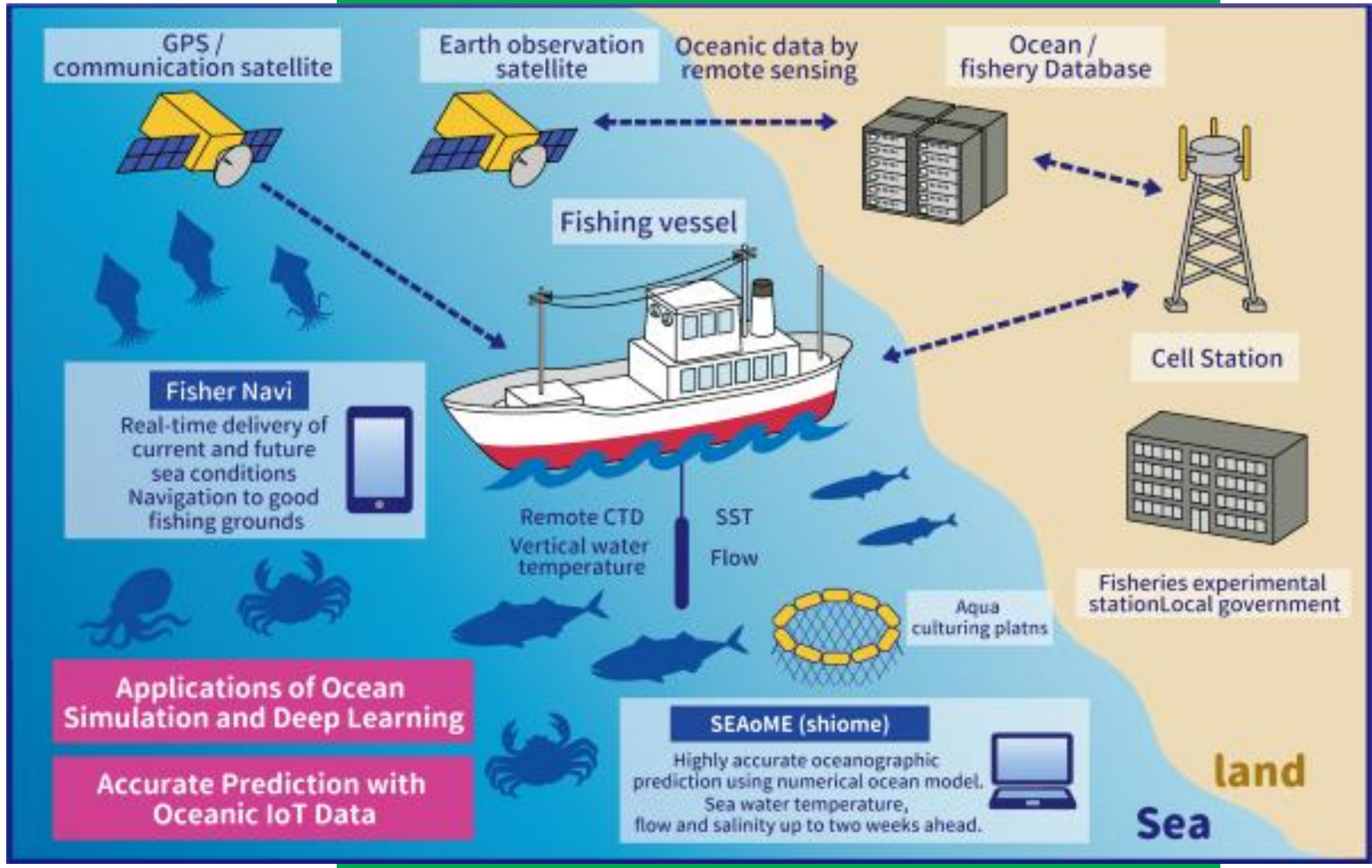
6. Technological & Innovation Shortfalls*

Indonesia's fisheries and aquaculture sectors, while vital to its economy and global seafood supply, face significant technological and innovation gaps that hinder productivity, sustainability, and competitiveness.

KEY CHALLENGES:
1. Limited Adoption of Advanced Monitoring and Automation
2. Disease Management and Biosecurity Deficiencies
3. Underdeveloped Genetic and Breeding Programs
4. Feed Dependency and Sustainability Gaps
5. Infrastructure and Technology Access Inequities
6. Traceability and Market Compliance Challenges



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a. Limited Adoption of Advanced Monitoring and Automation

- **Inefficient Data Collection**: Despite initiatives like FishFace, which uses onboard cameras for real-time catch monitoring, adoption remains limited. Over 90% of Indonesian fishing operations are small-scale, lacking resources to implement such technologies, leading to unregulated practices and overfishing [16].

- **Manual Feeding Practices**: Many aquaculture farms rely on manual feeding, resulting in over- or underfeeding, wasted resources, and pollution. Automated feeders and AI-driven systems (e.g., RAS) are underutilized, even though they can reduce feed waste by 20–30%.

b. Disease Management and Biosecurity Deficiencies

- **Reactive Disease Responses**: Shrimp farms face high disease prevalence (e.g., Vibrio, white spot syndrome), with only 10% complying with IndoGAP certification. Proactive biosecurity measures, such as microbiome analysis and pathogen testing, are rare, exacerbating mortality rates.

- **Antibiotic Overuse**: Over 75% of shrimp farms exceed recommended antibiotic doses, accelerating antimicrobial resistance (AMR). Alternatives like phage therapy or immunostimulant feeds are not widely adopted [19].

indoGAP
Indonesian Good Aquaculture Practices

indonesiashrimp.com

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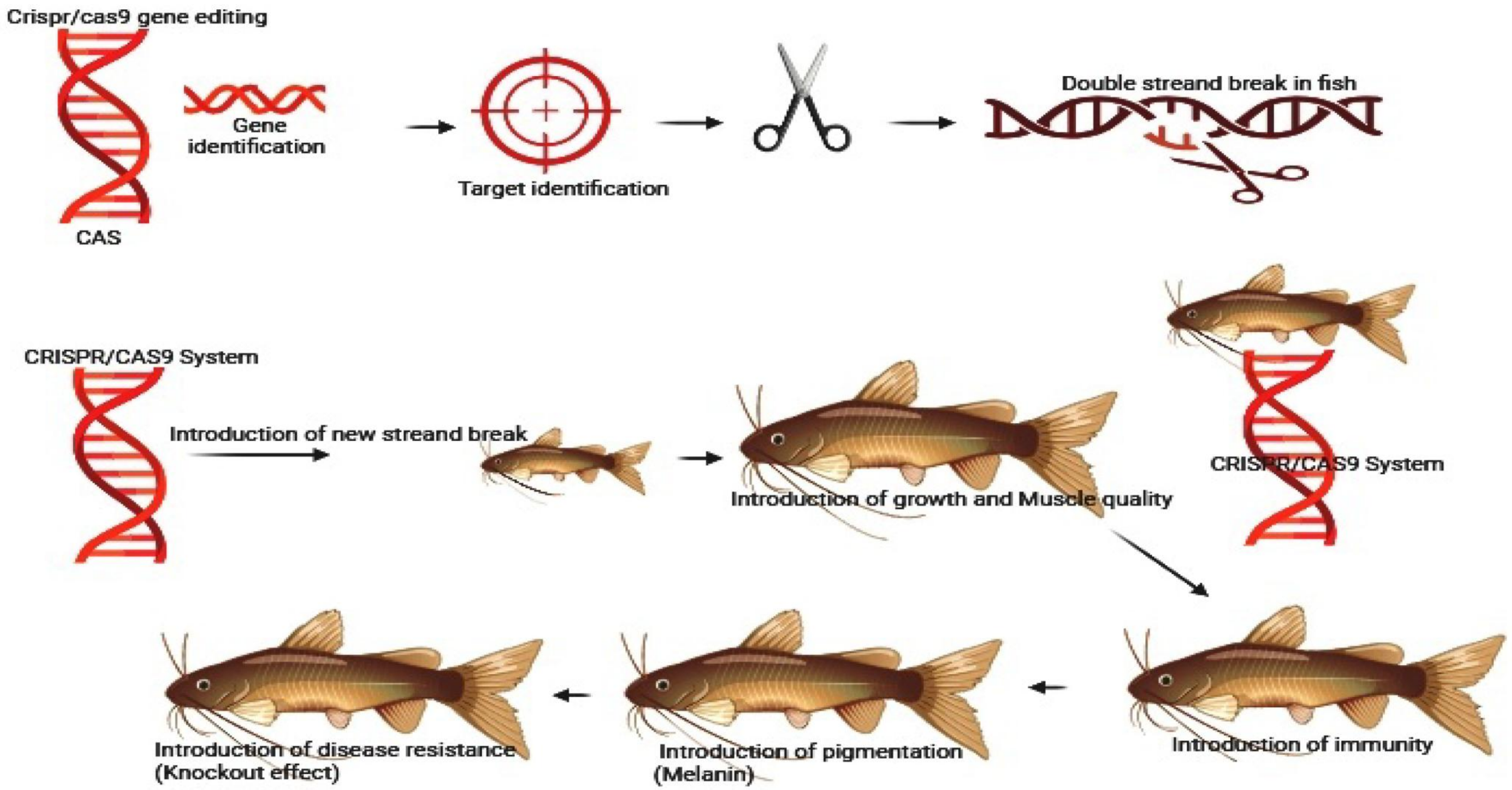
c. Underdeveloped Genetic and Breeding Programs

- **Lack of Resilient Strains**: Indonesia's seaweed sector suffers from a dearth of commercial hatcheries and research on high-yield, climate-resilient cultivars. This contrasts with Ecuador's success in shrimp productivity through localized genetic improvement [19].
- **Slow Adoption of Gene Editing**: While global aquaculture explores gene editing for disease resistance and growth efficiency, Indonesia lags due to limited funding and regulatory frameworks. This leaves farmers dependent on vulnerable wild stocks.

d. Feed Dependency and Sustainability Gaps

- **Reliance on Imported Ingredients**: Aquaculture feed accounts for 70% of operating costs, yet Indonesia depends on imported fishmeal and soy. Insect-based or algae-derived alternatives (e.g., Black Soldier Fly larvae) are not scaled due to high production costs (~€2,500–4,000/ton)[20].
- **Waste Recycling Deficits**: Fish processing by-products (e.g., heads, guts) are discarded instead of being converted into silage for feed, missing opportunities to reduce costs and environmental impact [20].



The application of CRISPR/Cas9 in aquaculture involves several steps. First, a specific gRNA is designed to match the target gene sequence. Then, the Cas9 protein binds to the target DNA, causing a double-strand break. Finally, the break is repaired.
Zhu et al. (2024)

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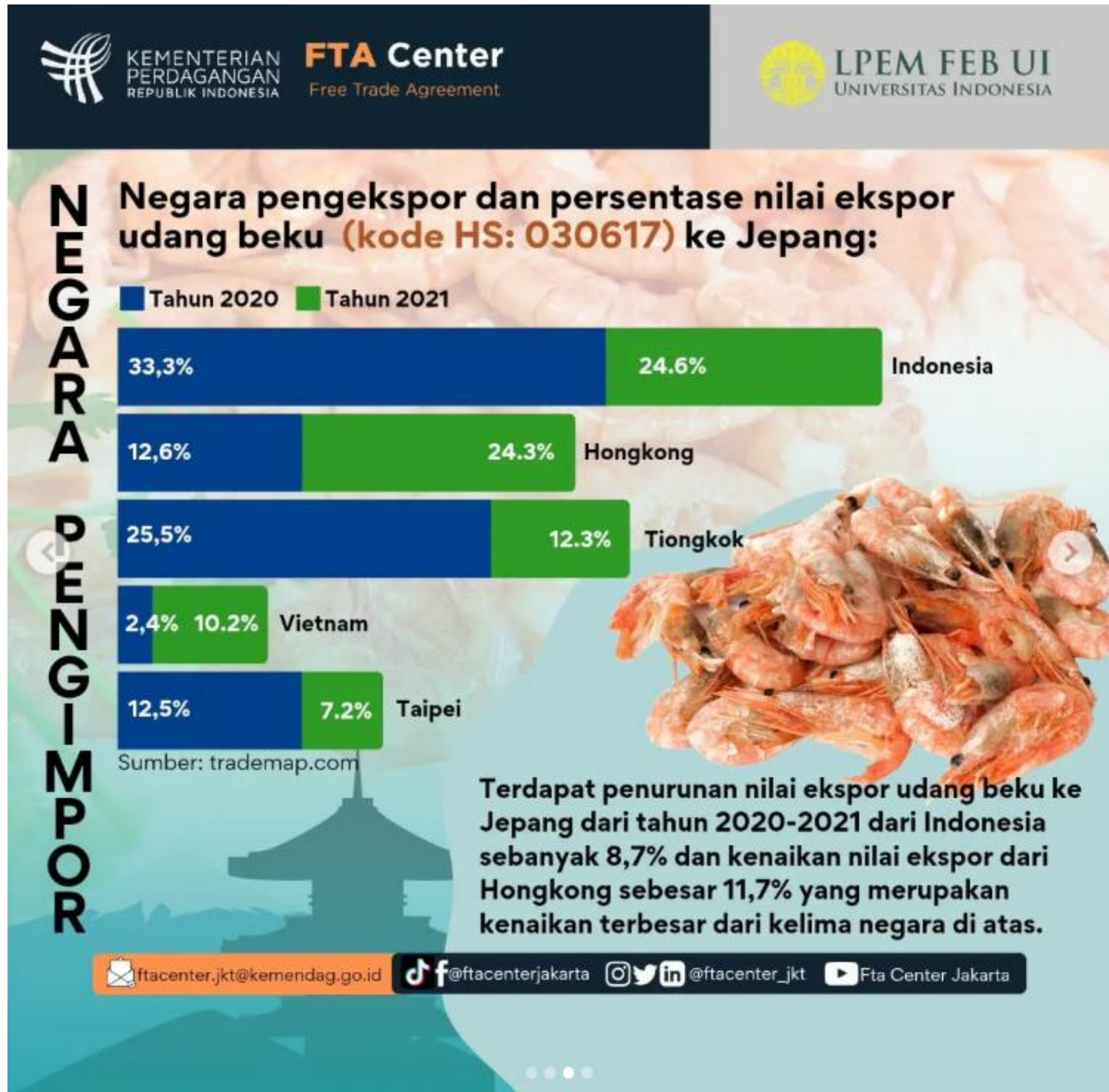
d. Traceability and Market Compliance Challenges

- **Weak Certification Frameworks**: Only 15% of global fisheries are certified (e.g., ASC, MSC), with Indonesian smallholders often excluded due to bureaucratic hurdles. Mislabeling and fraud further undermine market trust [16].

- **Blockchain Underutilization**: Despite global trends, Indonesia’s seafood supply chains lack blockchain or DNA barcoding for traceability, limiting access to premium markets like the EU and U.S.



e. Infrastructure and Technology Access Inequities

- **Smallholder Limitations**: Over 300,000 hectares of idle shrimp ponds require revitalization, but smallholders lack access to aerators, automated systems, or quality seeds. The AgResults project aims to bridge this gap but struggles with scalability [21].

- **Energy-Intensive Systems**: Recirculating Aquaculture Systems (RAS) and solar-powered solutions, which reduce water use by 95%, are rare due to high capital costs and limited technical expertise.

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a. **Public-Private Partnerships**: Collaborate with entities like the Sustainable Shrimp Partnership to scale biosecurity and certification programs.

b. **Research Investment**: Establish commercial seaweed hatcheries and fund gene-editing trials for climate-resilient species.

c. **Subsidy Reforms**: Redirect harmful subsidies toward RAS adoption, feed innovation, and smallholder training.

d. **Circular Economy Models**: Integrate fish waste recycling and IMTA (Integrated Multi-Trophic Aquaculture) to reduce dependency on wild resources.

Pathways for Improvement

CONCLUSION

Indonesia’s technological shortfalls in fisheries and aquaculture stem from fragmented policies, underfunded R&D, and inequitable access to innovations. Addressing these gaps requires prioritizing adaptive technologies, fostering international collaborations (e.g., ASEAN knowledge-sharing), and aligning growth with the FAO’s "Blue Transformation" agenda. By bridging these gaps, Indonesia can enhance food security, reduce ecological harm, and secure its position as a global aquaculture leader.

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Farid K Muzaki / ITS

+6281217762277
faridmuzaki@gmail.com
rm_faridkm@bio.its.ac.id

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