Food from the Oceans
Key drivers and challenges
an EU perspective

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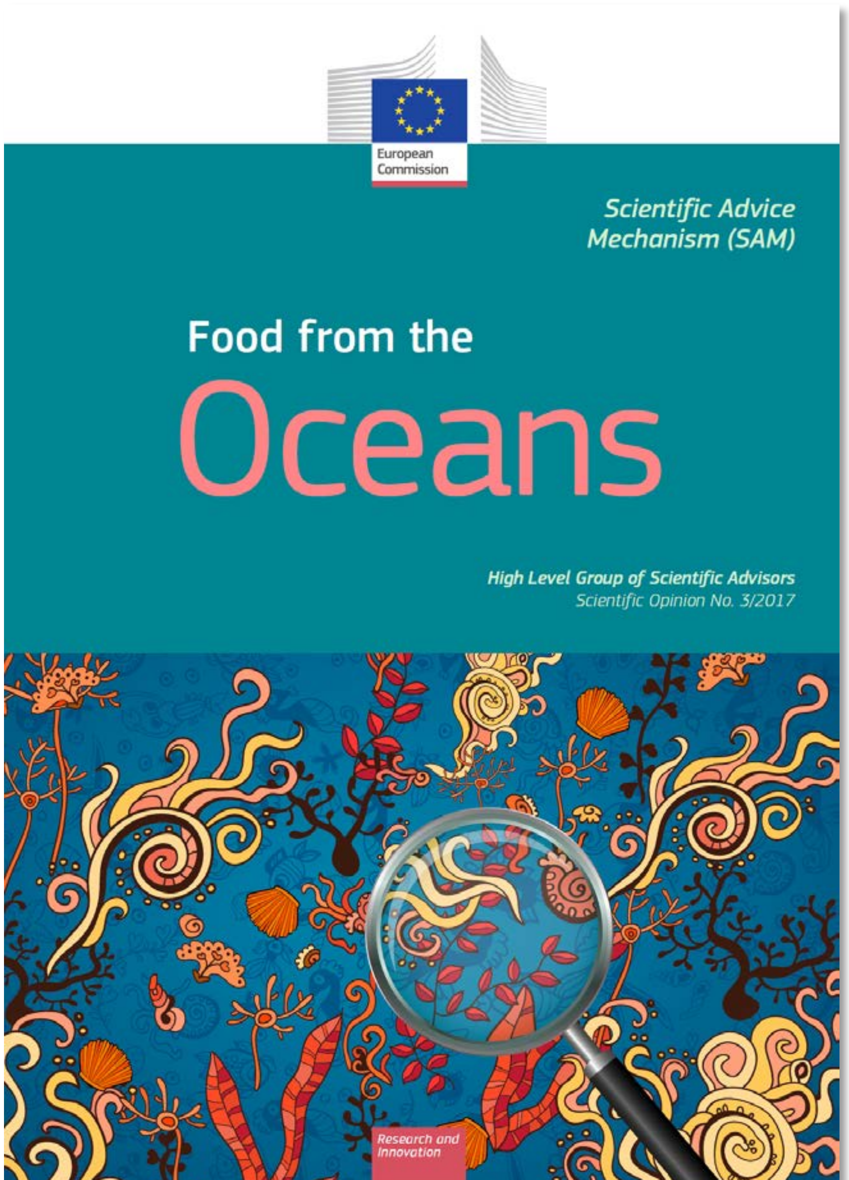
Marine Alliance for Science and Technology for Scotland

University of St Andrews

EMB ExCom and University Consortium Panel (70+ institutions)

Brussels, 28th September 2018

“How can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits?"



Key Conclusions:

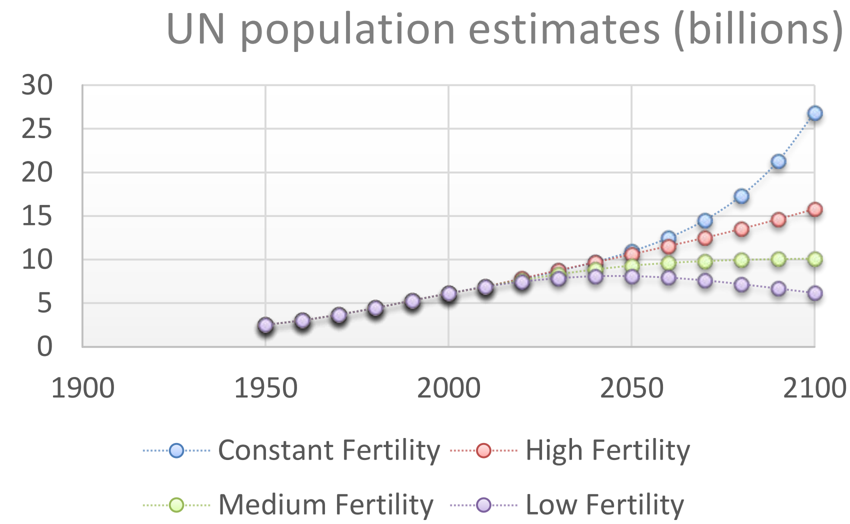
The scientific evidence unambiguously points to sustainable "culture" and "capture" at lower trophic levels (*i.e.* levels in the ocean food web below the carnivore levels currently mostly exploited) as the way to bring about such, an increase.

All sounds very sensible – from a scientific perspective!

But is it realistic? – A few thoughts……..

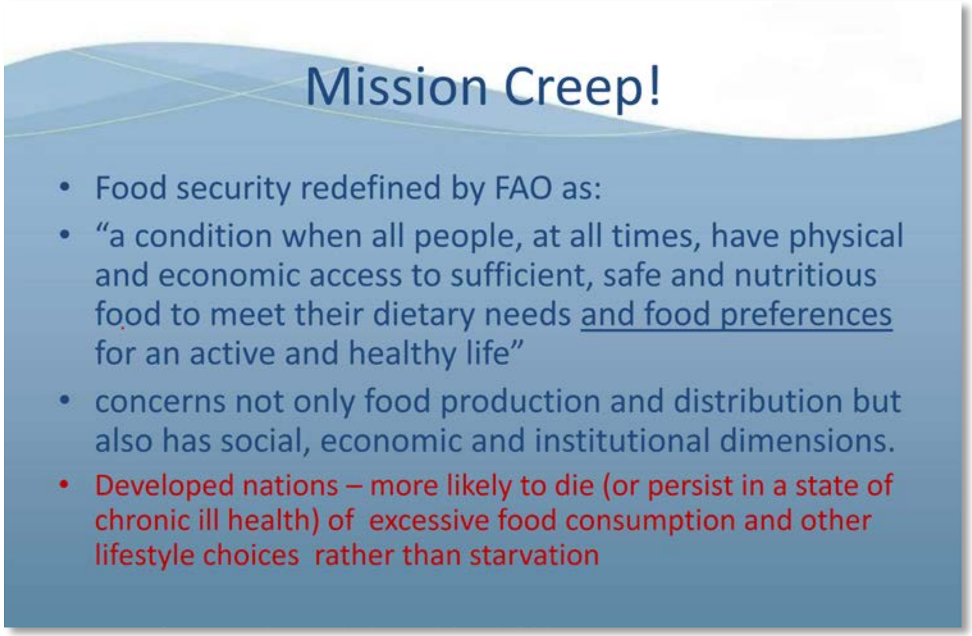
Why do we need to increase seafood production and how should we do it?

- World population ~9.8 billion – 2050
- Overall and *per capita* consumption seafood - increasing
- Ocean accounts for 50% of biomass production on earth, but only 2% calories/ 15% protein consumed as food
- The ecological efficiency of biomass production in water is higher than on land - ?

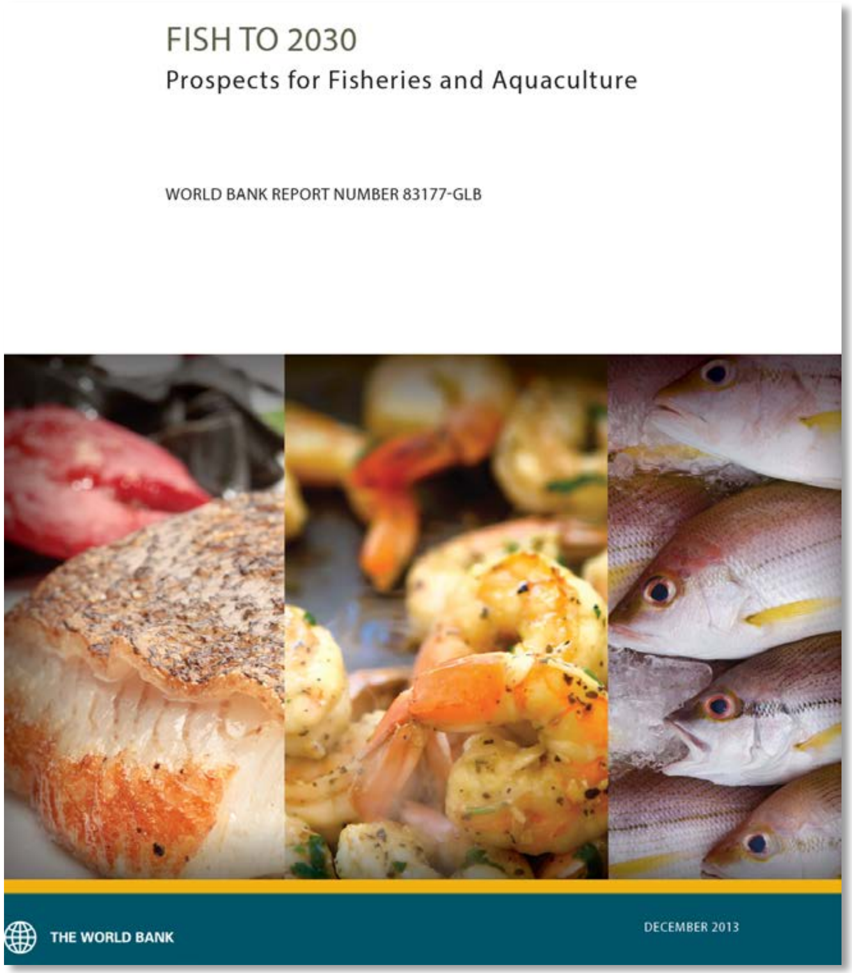


Broad Recommendations

- Better management and enforcement of regulation in existing capture fisheries
- Expansion of aquaculture
- Marine rather than freshwater production
- Capture and cultivation of seafood from lower trophic levels
    - lower trophic levels within capture fisheries – <u>including untapped mesopelagic resources</u>
    - lower trophic levels in aquaculture - <u>herbivorous fish, shellfish (molluscs) and algae</u>



Current status of seafood production?



Demand and Supply – World/EU

- Catching sector (~90m ton ceiling)
- Aquaculture (~55m ton)

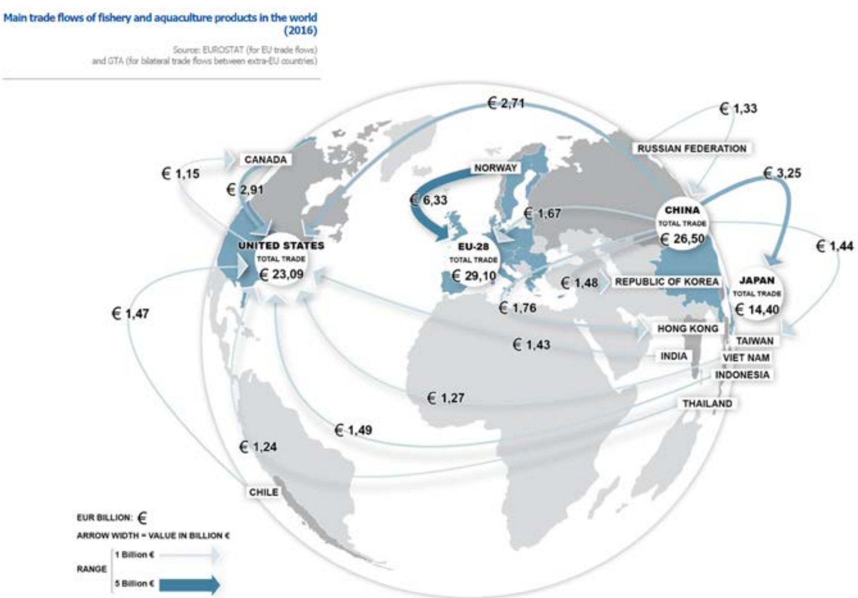
TABLE E.1: Summary Results under Baseline Scenario (000 tons)

	TOTAL FISH SUPPLY		FOOD FISH CONSUMPTION	
	DATA 2008	PROJECTION 2030	DATA 2006	PROJECTION 2030
Capture	89,443	93,229	64,533	58,159
Aquaculture	52,843	93,612	47,164	93,612
Global total	142,285	186,842	111,697	151,771
Total broken down by region as follows				
ECA	14,564	15,796	16,290	16,735
NAM	6,064	6,472	8,151	10,674
LAC	17,427	21,829	5,246	5,200
EAP	3,724	3,956	3,866	2,943
CHN	49,224	68,950	35,291	57,361
JAP	4,912	4,702	7,485	7,447
SEA	20,009	29,092	14,623	19,327
SAR	6,815	9,975	4,940	9,331
IND	7,589	12,731	5,887	10,054
MNA	3,518	4,680	3,604	4,730
AFR	5,654	5,936	5,947	7,759
ROW	2,786	2,724	367	208

Source: IMPACT model projections.
Note: ECA = Europe and Central Asia; NAM = North America; LAC = Latin America and Caribbean; CHN = China; JAP = Japan; EAP = other East Asia and the Pacific; SEA = Southeast Asia; IND = India; SAR = other South Asia; MNA = Middle East and North Africa; AFR = Sub-Saharan Africa; ROW = rest of the world.

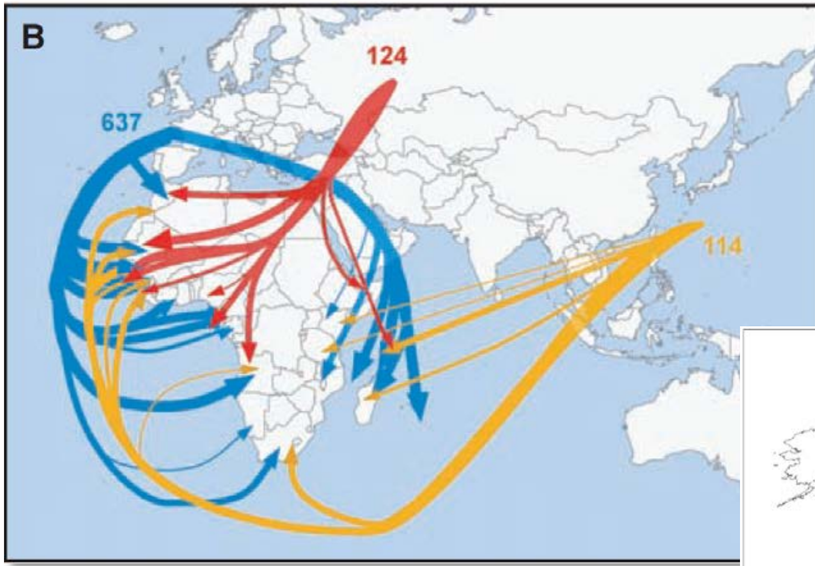
UN FAO has identified a food gap with seafood, if production does not increase to keep pace with demand. It is predicted that global seafood demand will exceed 260 million tons by 2030 and that the current predicted supply at today's rate will be 210 million tons. **This 50 million ton shortfall in production will need to come from aquaculture? [1m ton EU and Central Asia]**

BUT!



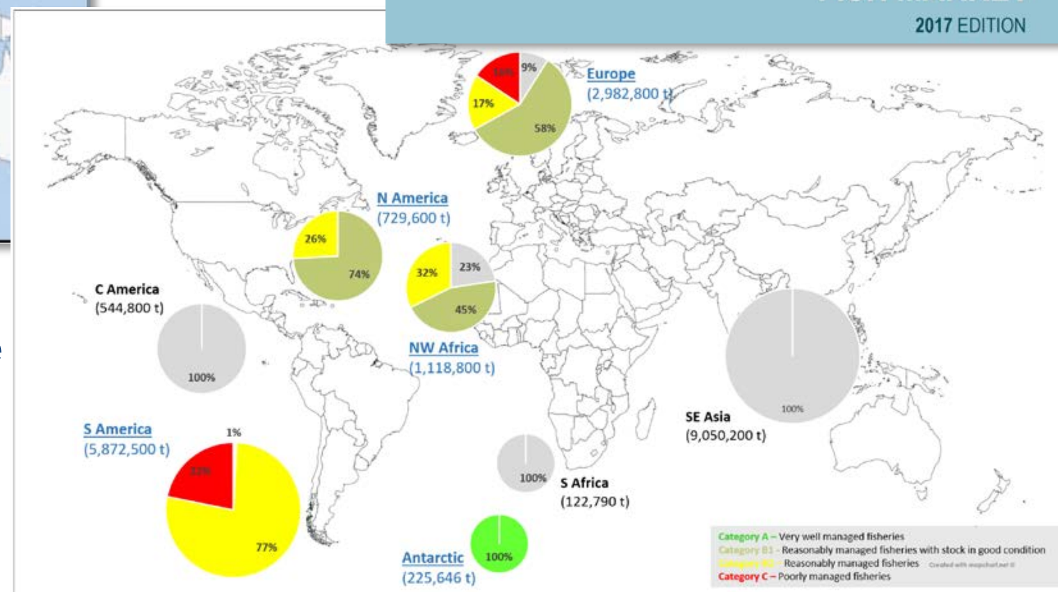
- EU – largest global trader of fishery and aquaculture products in terms of value
- 2016
  - EUR 54.3 billion 14.1 m tonnes
  - EURO 24.4 billion trade deficit
  - Self-sufficiency ratio (p/c) – 46%
- Tuna, cod, salmon
- Wild products ~74%

Exporting the problem



Movement of fishing effort from developed nations to Africa in the 1990s. Data indicate total access years in distant-water fishing agreements.

Worm et al. 2009. Rebuilding global fisheries. Science 325(1173146).



Veiga et al. 2017. *Reduction Fisheries: SFP Fisheries Sustainability Overview 2017*. Sustainable Fisheries Partnership Foundation. 34 pp. sustainablefish.org.

Capture fishery – Key Challenges/Opportunities

- Reducing bycatch and discards – using innovative technologies
- Monitoring and regulation facilitated by new technologies - AI/Robotics
- Understanding the broader ecosystem context of exploiting lower trophic level fisheries

- Discards – "landings obligation" – implications and unintended consequences
- Data deficiencies – non-quota stocks
- Ecosystem Approach – for mixed stock fisheries
- Gear selectivity – Bycatch and discard reduction - intelligent fishing gear !
- Novel fisheries management approaches - Catching credits / VMS/AIS etc
- Small scale fisheries (80% of EU and majority of fishers globally)
- Monitor compliance and enforce regulations - Use of new technologies for monitoring (open source – low cost)
- Use of robotics and AI – monitoring and stock assessment
- Social – Economic
  - Ageing workforce
  - Better economic opportunities elsewhere
  - Psychological/behaviourial change drivers
  - Marine Panning and Governance – "ownership and responsible fishing"
  - Displacement – MPA/Renewables
  - Industry is disjointed /dispersed/structurally complex

Aquaculture - 50 years on - so how are we doing?

Research Requirements

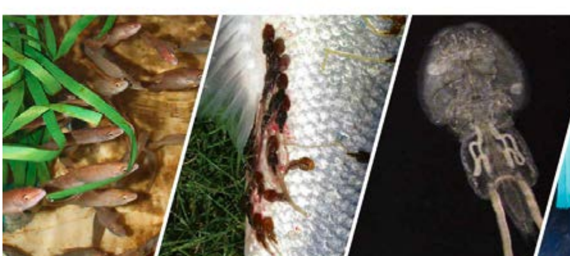
01 Nutrition

Research Requirements

02 Stock Improvement

Research Requirements

03 Health & Welfare



Research Requirements

04 Food Safety & Hygiene

Research Requirements

05 Technology & Engineering

Research Requirements

06 Wild-Farmed Interactions

Research Requirements

07 Capacity

Research Requirements

08 Markets, Economics & Social Science

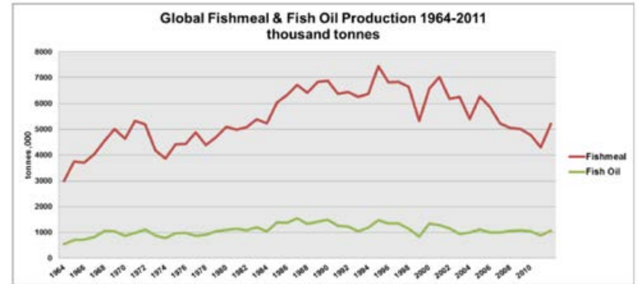
Research Requirements

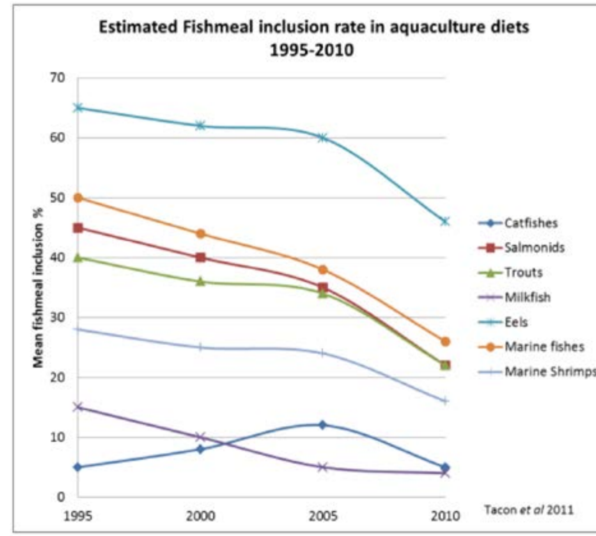
09 Blue Biotechnology & Growth

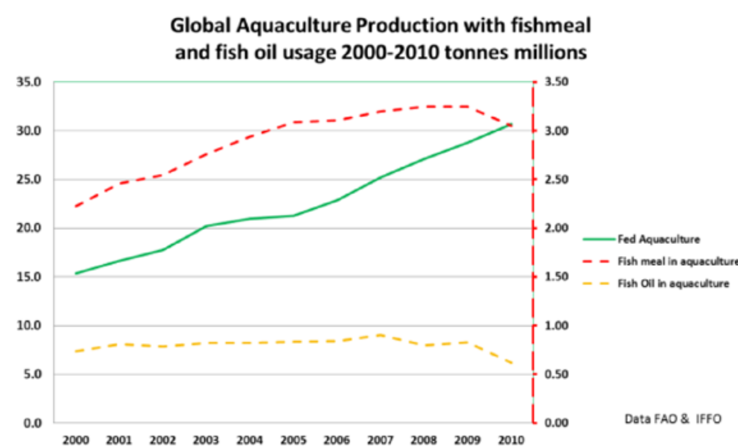
01 Nutrition

- Mid 1990s – sustainability of (fed) aquaculture closely linked to fish meal and fish oil
- Fish meal and fish oil replacements (EHA-DHA) – continuing area of research
- Strategic use - meal for broodstock and early life stages, oil for finishing diets
- Certification schemes (IFFO RS)
- Concerns remain re fish meal and oil derived from Asian tropical mixed fishery

GM – Camolina for Omega 3? Still requires land based production – fertiliser and pest/herbicides!







02 Stock Improvement

Using available/heritable genetic traits – not transgenics

- Selective breeding programmes (for salmonids/tilapia – but not shellfish!)
- Production of fish/shellfish with traits for higher production value (NGS)
- Stock management strategies to help productivity (Molecular markers)
- Genetic management and improvement of new fish and shellfish species (Transcriptomics)
- Epigenetic and maternal programming (Novel sequencing)
- Environmental manipulation
- Disease resistance – Sealice?
- Gender control and sterility – growth/wild interactions

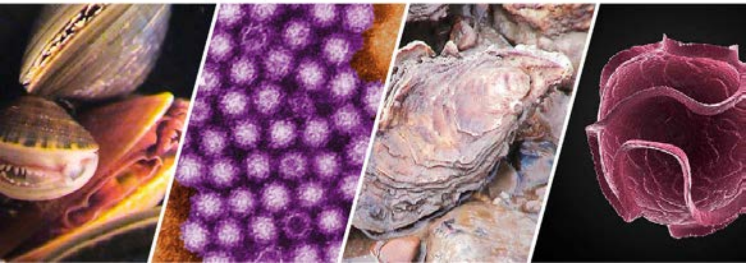
03 Health & Welfare

Prevention and cure!
Sealice cost the salmon industry >£30m/yr

- ~60% of UK aquaculture R&D expenditure related to "Health and Welfare" – mainly diseases of salmon!
- Disease results in serious financial loss and compromises fish welfare
- A range of bacterial and viral pathogens – ISA, AGD, VHS, PD, Saprolegnia, Furunculosis etc.
- Significant advances in treatment – reduction in the use of antibiotics, increase in multivalent vaccines and chemotherapeutants
- **BUT serious limitations on availability of licenced medicines**
- Emphasis is on prevention through good biosecurity and prophylaxis
- Sea lice remain the biggest single challenge – for farmed (and wild salmon)
- Between farm transmission mechanisms – sealice!
- Within site farm management practices
- Alternate therapeutants/treatments – preventing resistance
- Health and welfare of cleaner fish (lump sucker/wrasse) – sealice!
- Welfare (important – but often ignored!)
- Genetics and breeding
- Emerging diseases – CLIMATE CHANGE!

Chilean salmon producers using 1,400 times the amount of antibiotic per ton than Norway! (FFT 2018)

04 Food Safety & Hygiene

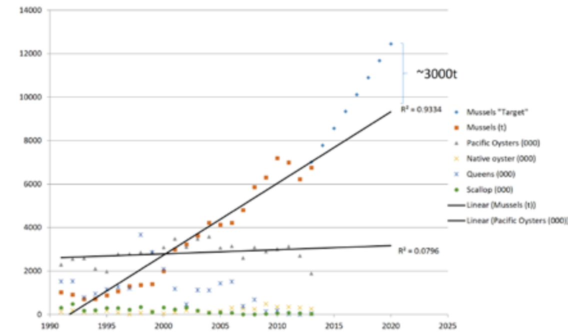


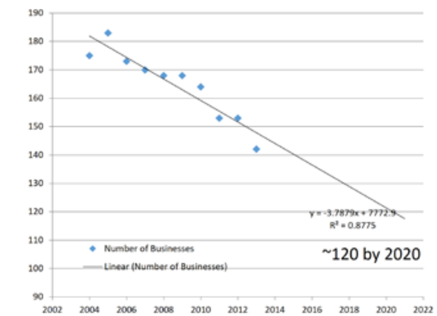
- Detection, quantification and management of algal biotoxins in shellfish production
- Ecophysiology of Harmful Algal Species and microorganisms
- Norovirus detection and management (regulatory driver)
- Environmental quality of shellfish growing waters
- Traceability

Conundrum of scale and sectoral value vs cost of regulation and protecting public health!

How does this fit with the proposal to massively increase bivalve shellfish production?

Where are we now?
Table Production





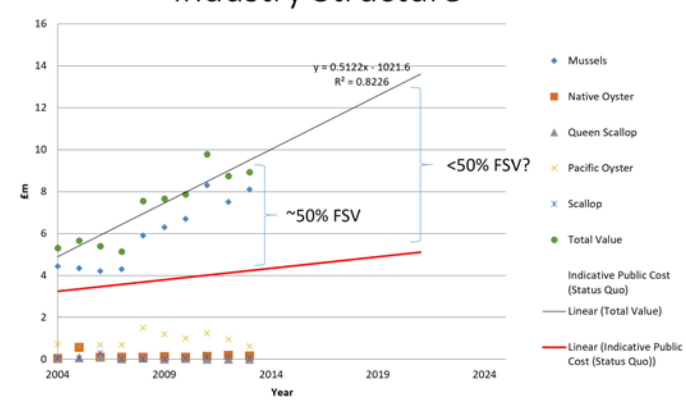
Mussels – 10 companies produce 74% of production

Pacific Oysters – 2 companies account for 33% of production
MS – Stats 2013

- Small number of "large" players
- Large number of "small" players

Significant differences in "business vision/agenda"

Industry Structure



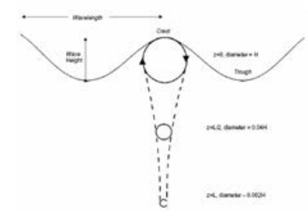
FSV as Function of Public "Cost"
A rough estimate!

05 Technology & Engineering

- Location to open water sites (biological, technical, economic and climate change constraints)
- Non-chemical treatment of Sea lice
- Anchors and moorings
- Sensors, automatic monitoring and intelligent systems
- Anti-predator developments
- Co-location with and multi-use of existing and new marine structures
- Closed containment
- Seaweed and algae cultivation (economic realities)

Equation 1. $D_z = H^{(2z/L)}$

D = diameter of the orbit; z = depth; L = wavelength (Pond and Pickard, 1983).



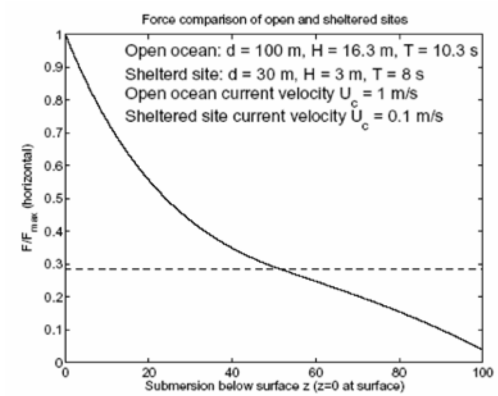


Figure 22. A comparison of an extreme open ocean conditions of waves and currents and sheltered site conditions of low waves and weak currents using Equation 2 (dotted line indicates that a submersion in the open ocean of about 31m will result in loads comparable with those at surface at a sheltered site (F/Fmax (horizontal) = maximum horizontal force, d=depth in metres, H = maximum wave height in metres and corresponding wave period, T in seconds, U_c = current velocity in meters per second) (after Ágústsson, 2004).

06 Wild-Farmed Interactions

Sealice and escapes dominate this area

- The dispersal patterns of wild sea trout and salmon and subsequent distribution in relation to the Scottish Coast
- The effects of sea lice at a population level on wild salmonids
- Improving understanding of sea lice dynamics
- Escapes of farmed fish
- Predator control

- Investigations of routes of emergence from subclinical infection of wild fish to disease in farmed fish

07 Capacity

Never under estimate the need for social licence

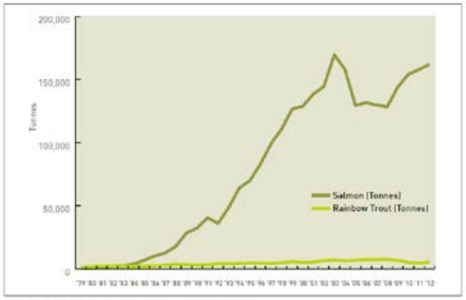


Figure 6 | Scottish farmed marine finfish production 1979-2012.

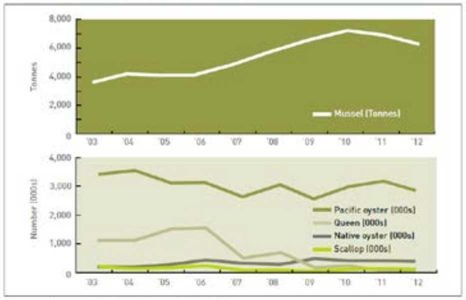


Figure 7 | Scottish farmed shellfish production 2003-2012.

- Improved inshore capacity estimates would allow greater certainty as to the appropriate sustainable capacity for new development
- Improved estimates of assimilative and biological carrying capacity for fish and shellfish farms in inshore and offshore marine ecosystems
- Optimisation of site selection for disease management (cf Wild-Farmed Interactions) – sea lice!
- Improved management of shellfish aquaculture to account for changing environmental conditions - climate change
- Is Integrated Multi Trophic Aquaculture really a viable solution?

08 Markets, Economics & Social Science

New species diversification may present opportunities – but remember the cod tale!

- Human Capital – training and skills development
- Consumers and new markets – social licence
- Impact assessment and appraisal – more sophisticated approaches
- Governance
- Sector competitiveness – need to think globally
- Finance and investment – still considered a risky business!
- Production techniques and technologies

09 Blue Biotechnology & Growth

- Marine Biotechnology exploitation
  Nagoya Protocol?
- Health – neutraceuticals/novel compounds
- Environment – bioremediation / extremophiles – depth/temperature /pressure etc
- Food
- Energy – micro/macro algae?

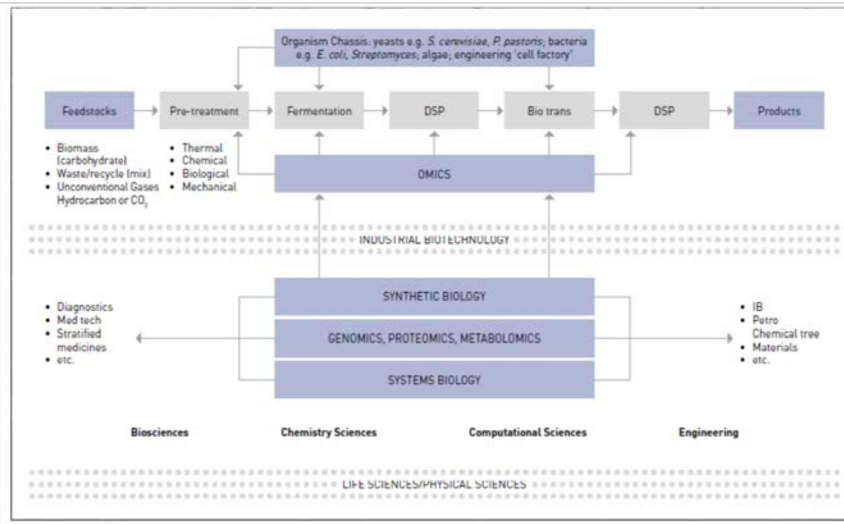


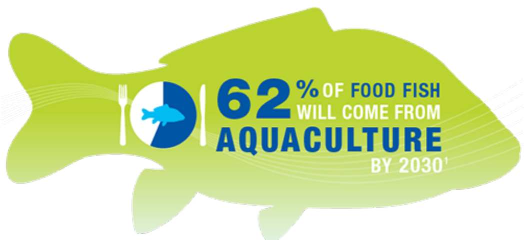
Figure 8 | An illustration of IBioIC converage of the entire integrated bioprocessing span (from the IBioIC Non-Confidential Executive Summaryc).

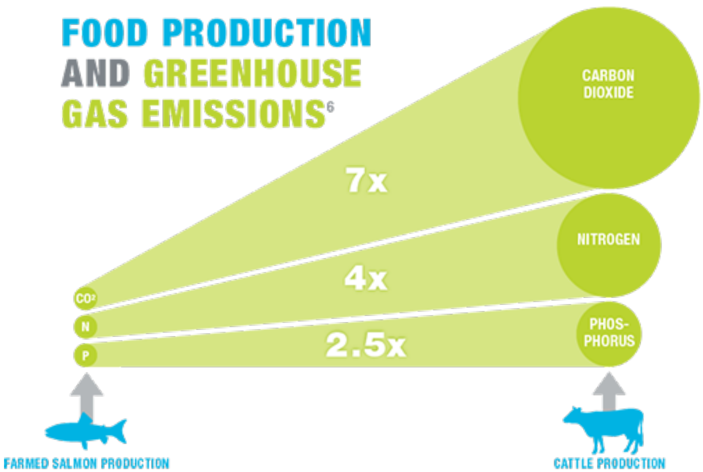
Aquaculture – Key Challenges/Opportunities

- **Progress over the last 50 years has been significant and unprecedented ……BUT……..**
- Multi-annual National Plan 2020 Targets 2030 Growth targets ?? Are we on track? Are they achievable?

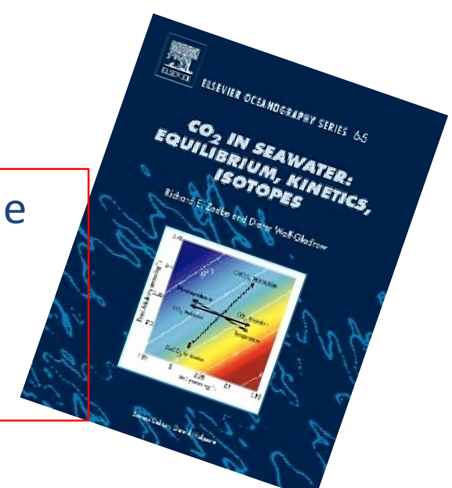
- **Nutrition** – feed sustainability – *fish meal and oil substitution*
- **Stock improvement** – significant advances probably, transformational change possible
- **Wild/farmed Interactions** –escapes/predators/disease?
- **Food Safety and Hygiene** – continued investment to maintain and improve – risk-based regulation
- **Engineering and technology** – significant advances probable.
- **Capacity** – suitable sites of suitable size – mitigating environmental impacts – refining regulation?
- **Markets, Economics and Social Science** – strategic investment – lower trophic levels???
- **Blue biotechnology** – promise to profit?

Ecological/Environmental Footprint – need the full picture!





Bivalve aquaculture – "non-fed" – but there is still an environmental cost.



When $CaCO_3$ is removed from seawater, its pH shifts toward the acidic, and the CO_2 concentration and pCO_2 of the water increases, **leading to increased concentrations of CO_2 in the atmosphere.**

Comparing Like with Like!

Feed conversion efficiency in aquaculture: do we measure it correctly?

Jillian P Fry[1,2,3,6], Nicholas A Mailloux[1], David C Love[1,2], Michael C Milli[1] and Ling Cao[4,5]

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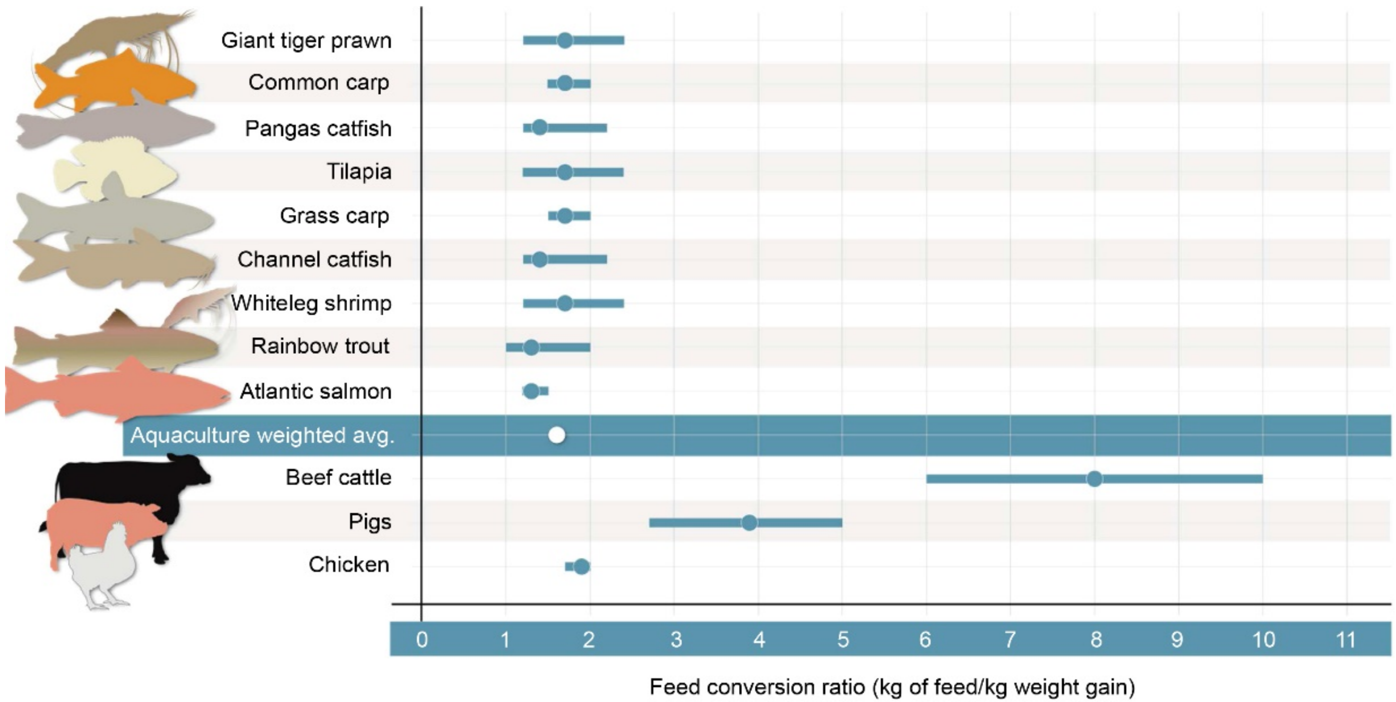
Environmental Research Letters, Volume 13, Number 2



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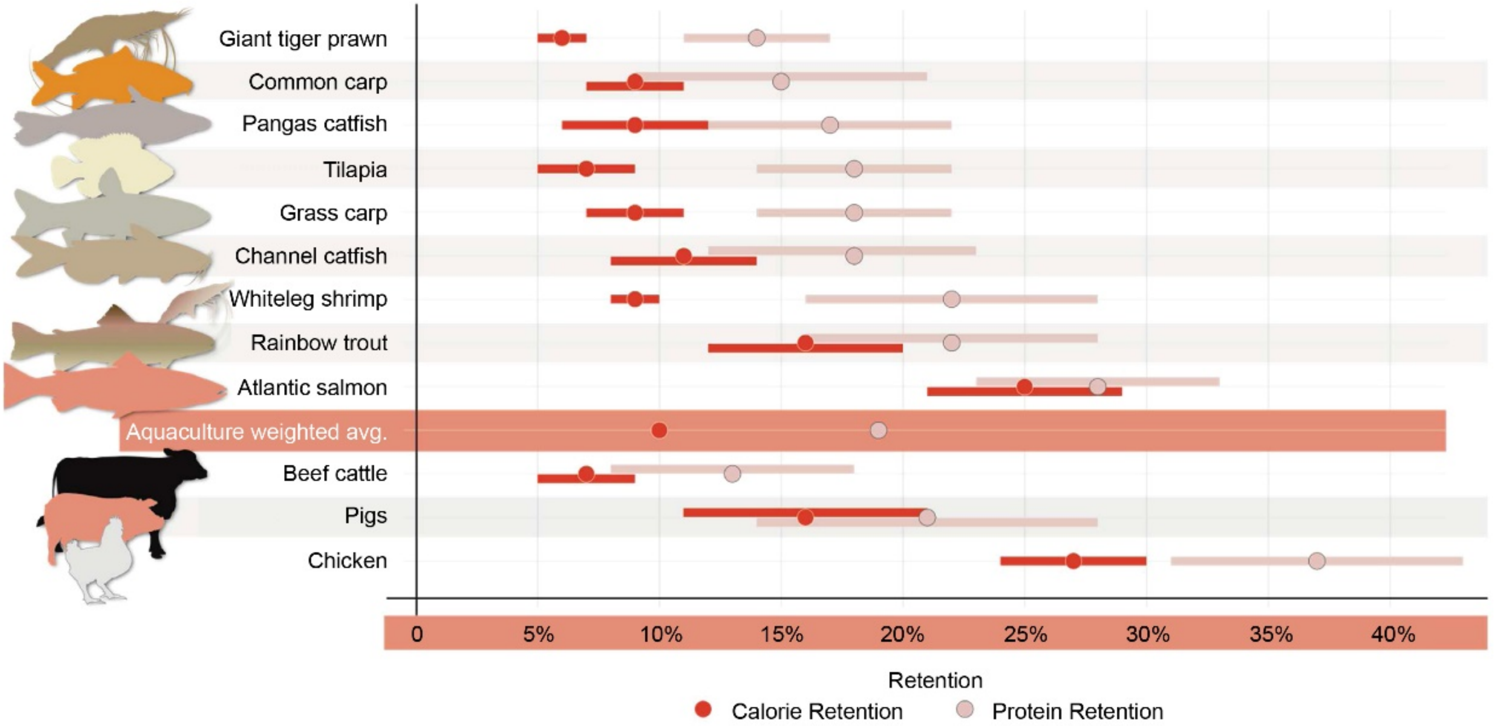
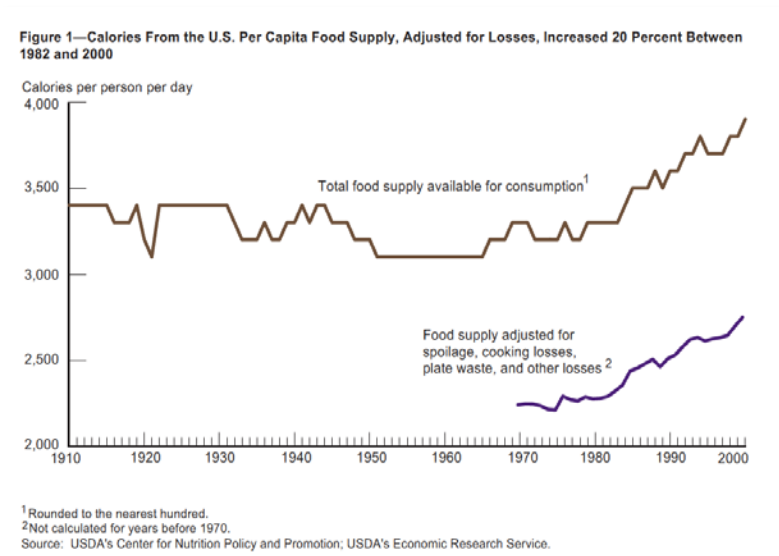


- Averaged over all categories, caloric and protein efficiencies are 7%–8%. At 3% in both metrics, beef is by far the least efficient. We find that reallocating the agricultural land used for beef feed to poultry feed production can meet the caloric and protein demands of ≈120 and ≈140 million additional people consuming the mean American diet, respectively, roughly 40% of current US population.
- http://iopscience.iop.org/article/10.1088/1748-9326/11/10/105002

Food Waste – supply chain

- 30-50% (1.2-2 billion tonnes of all food is wasted



Putnam *et al* 2002. FoodReview, Vol. 25, Issue 3; Economic Research Service, USDA (above figures for the USA).

Food Waste – consumption


U.S. Per Capita Food Supply Trends: More Calories, Refined Carbohydrates, and Fats

Judy Putnam, Jane Allshouse, and Linda Scott Kantor

The average American dietary style at the beginning of the 21st century resembles an hour glass rather than the Federal Government's Food Guide Pyramid. We gobble huge amounts of added fats and sugars from the top tier of the Pyramid (marked "Use sparingly") and heaping plates of pasta and other refined grains from the bottom tier, but we are sorely lacking in the vegetables, fruits, low-fat milk products, and other nutritious foods in the middle of the Pyramid.

A big jump in average calorie intake between 1985 and 2000 without a corresponding increase in the level of physical activity (calorie expenditure) is the prime factor behind America's soaring rates of obesity and Type 2 diabetes. ERS's loss-adjusted annual per capita food supply series (adjusted for spoilage, cooking losses, plate waste, and other food losses accumulated throughout the marketing system and the home) suggests that average daily calorie consumption in 2000 was 12 percent, or roughly 300 calories, above the 1985 level (fig. 1). Of that 300-calorie increase, grains (mainly refined grains) accounted for 46 percent; added fats, 24 percent; added sugars, 23 percent; fruits and vegetables, 8 percent; and the meat

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The authors are agricultural economists with the Food and Rural Economics Division, Economic Research Service, USDA.

According to a recent survey, the number of American adults who say they are eating "pretty much whatever they want" is at an all-time high.

Credit: PhotoDisc.

2 FoodReview, Vol. 25, Issue 3 — Economic Research Service, USDA

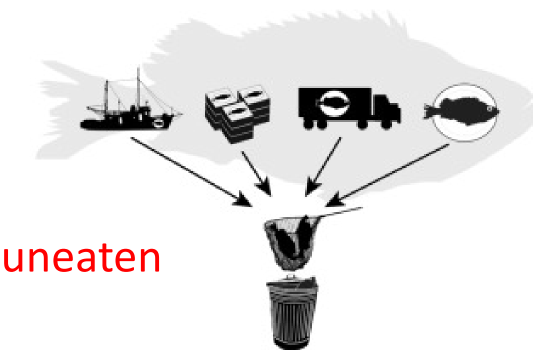
- Obesity rates in most of the developed world are increasing!
- US 72% of men and 68% of women – overweight or obese.
- UK 24% of men and 26% of women - obese. For children attending reception class (aged 4-5 years) during 2011-12, 9.5% were obese.

- **Overeating is a main cause of overweight and obesity**

- Easy access to cheap, high-energy food - often aggressively marketed to people
- Sedentary lifestyle's - too much time sitting down
- People drive or use public transport and walk a lot less than they used to.
- Working and living in temperature controlled environments

- Large proportion of population in developed countries could probably eat 25% less calories!
- Double whammy – developed countries eat more food and waste more food *per capita*

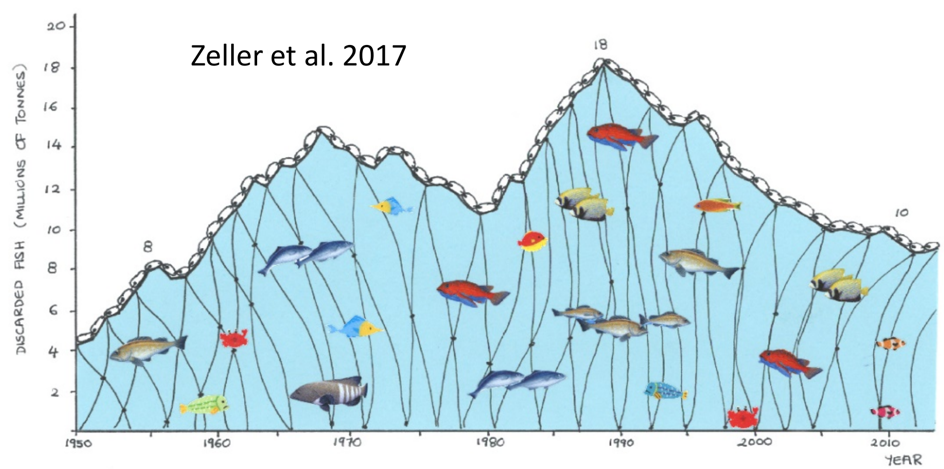
But what about seafood?



2009 – 2013 ~ 40 to 47% edible US seafood supply was uneaten

51 - 53% wasted by the consumer
16 – 32% bycatch discarded
13 –16% distribution and retail operations
Seafood lost ~ 36% of gap (DHA/EPA) between current and recommended levels of consumption.

Love et al. 2015



Summary - Some final thoughts

Are we really going to:

- Consume more herbivorous fish or are we more likely to adapt those species we want to eat by growing them more efficiently on plant proteins and plant/algae derived EPA/DHA?
- Massively increase filter feeding bivalve production when the market is limited and consumers will find more palatable/acceptable protein sources? – is this really an option for the developing world where coastal pollution is likely to increase?
- Grow macro algae – a high volume, low value commodity with limited uses and markets?
- Persist with Integrated Multi-Trophic Aquaculture (IMTA) – when there is no real evidence that the environmental, economic and industry demand for it exists (in Europe)?
- Move aquaculture "offshore" – or just slightly more exposed locations and intensify production (with recirculating land-based components)?

How much could we achieve through focusing on waste reduction?

European Marine Board – Advancing Seas & Ocean Science

University of St Andrews | FOUNDED 1413

CRMG – Coastal Resources Management Group

Marine Alliance Science Technology Scotland

Summary - Key Points

1. Ruthlessly focus on and innovate, to reduce waste throughout the seafood supply chain
2. Optimise the sustainability of capture fisheries
    1. Reducing bycatch and discards - monitoring and regulation - facilitated using new technologies - AI/Robotics
    2. Understanding the broader ecosystem context of exploiting lower trophic level fisheries

    [Chapter 2 – Navigating the Future V]
3. Continue to develop and expand <u>sustainable</u> aquaculture – the seafood consumers want + lower trophic level production as raw materials and feed

4. Develop holistic projects that are truly transdisciplinary – researchers/regulators/industry… from the outset – to avoid myopic outputs and outcomes!

European MARINE BOARD Advancing Seas & Ocean Science

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CRMG Coastal Resources Management Group

MARINE ALLIANCE SCIENCE TECHNOLOGY SCOTLAND

CRMG

Coastal Resources Management Group

Questions?

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