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Marine Biotechnology: *Enabling Solutions for Ocean Productivity & Sustainability*

Rachael Ritchie,
Director Business Development,
Genome British Columbia, Canada

Outline

- Marine biotechnology renaissance
- Talk about the potential of marine biotechnology
- Identify challenges to realising this potential

Marine bioscience & biotechnology : 4 areas

Marine organism production

- Organism cultivation and collection
- Disease control and monitoring
- Marine biosafety
- Mass production e.g. seaweeds

New Materials

- Drug discovery
- Health supplements, nutraceuticals
- Industrial materials
- Biofuels and bioenergy
- Biorefining

Organism-based Technology

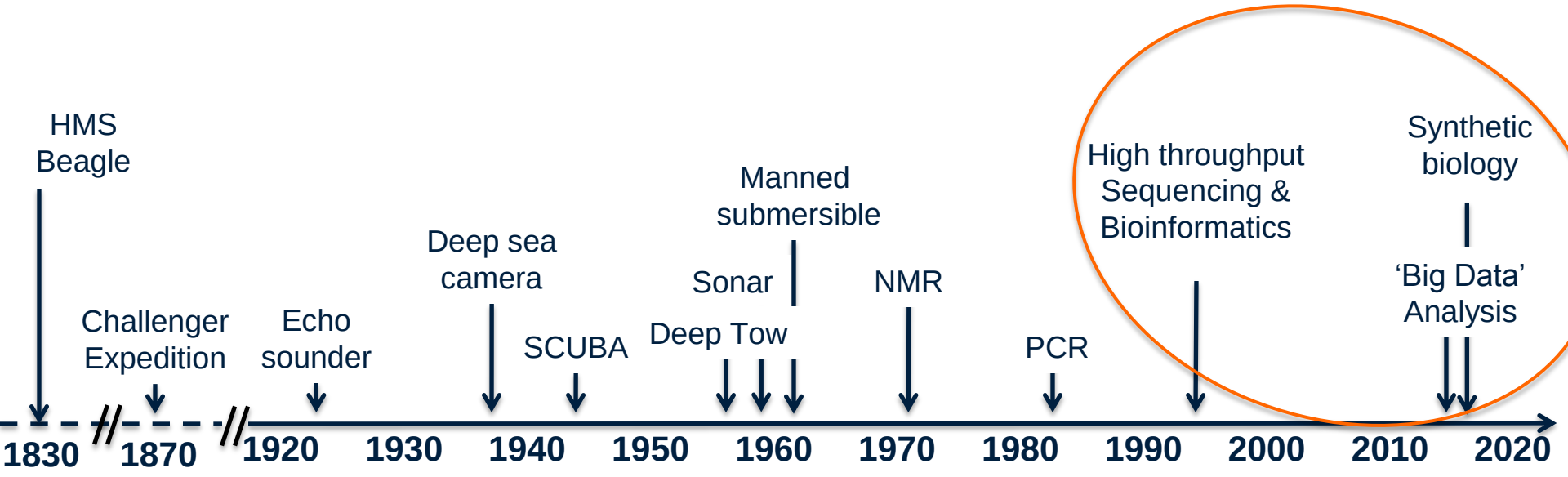
- Bioprospecting
- Marine genome sequence and bioinformatics
- Metagenomics and other omics technologies

Marine conservation

- Monitoring environmental change
- Pollution prevention and control
- Biodiversity conservation and ecosystem recovery

A changing landscape for marine biotechnology

- increased our understanding of ocean bioresources
- renewed interest in the field of marine biotechnology

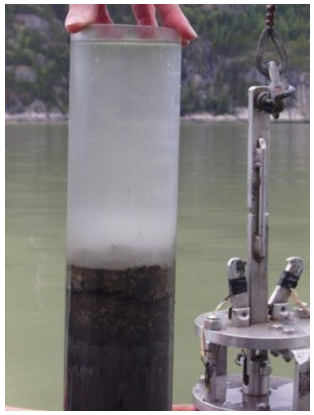


CENSUS OF MARINE LIFE

4-5 new species every day

Metagenomics of marine environment

A new tool in the toolbox



Environmental sample

DNA extraction

DNA of all species present in the environment

Sequencing of selected taxa

Next generation sequencing (NGS) of global diversity

1 litre seawater contains (2006!):
- bacteria: 20,000 ‘types’
- viruses: vast, unknown

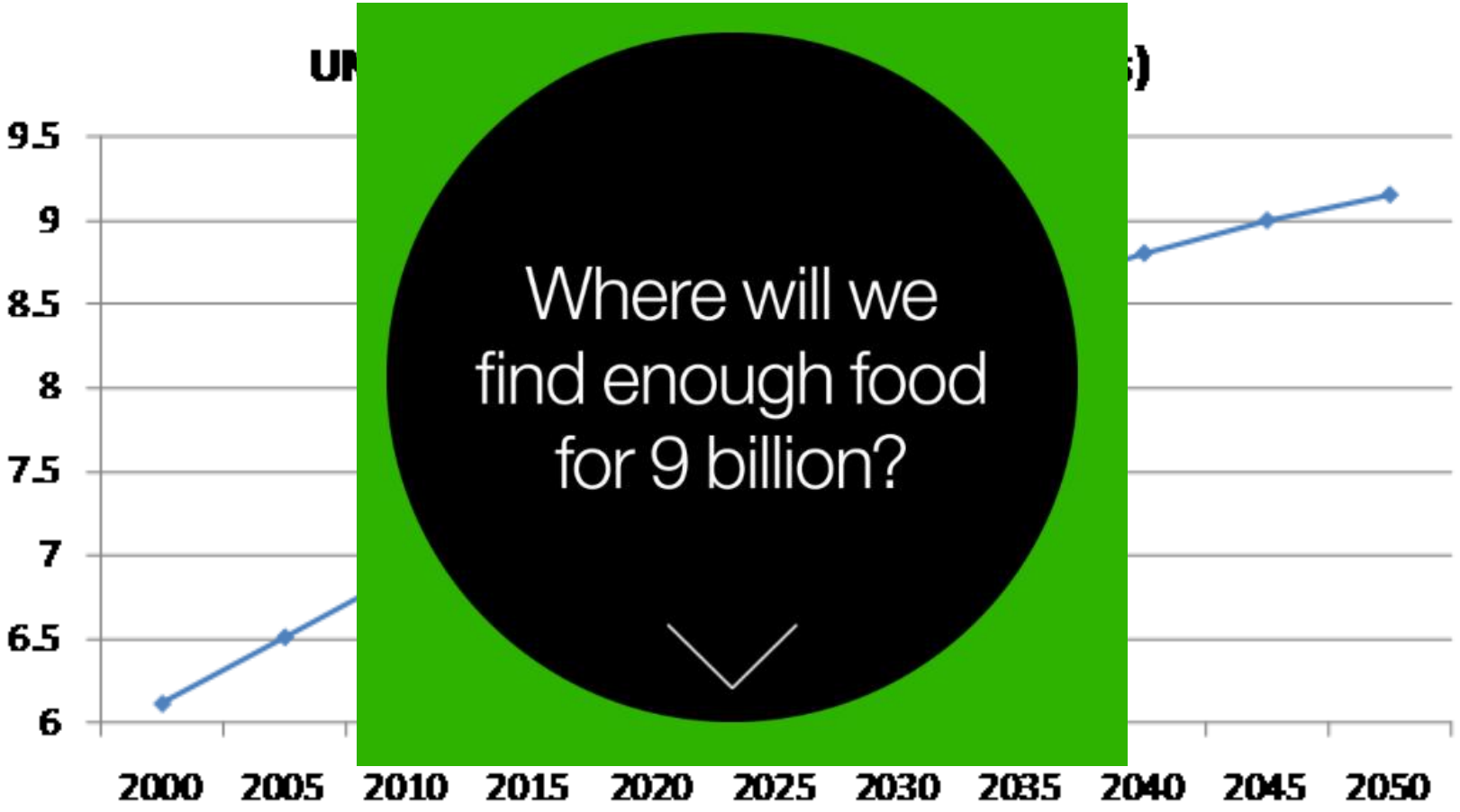
Marine biotechnology and grand challenges

Viewed as a way to address global grand challenges:

- Pursuing human **health** and well-being
- Sustainable supply of high quality **food**
- Developing sustainable sources of **energy** alternatives to crude oil and gas
- New **industrial products and processes** with lower GHG emission
- **Protection and management** of the already stressed marine environment

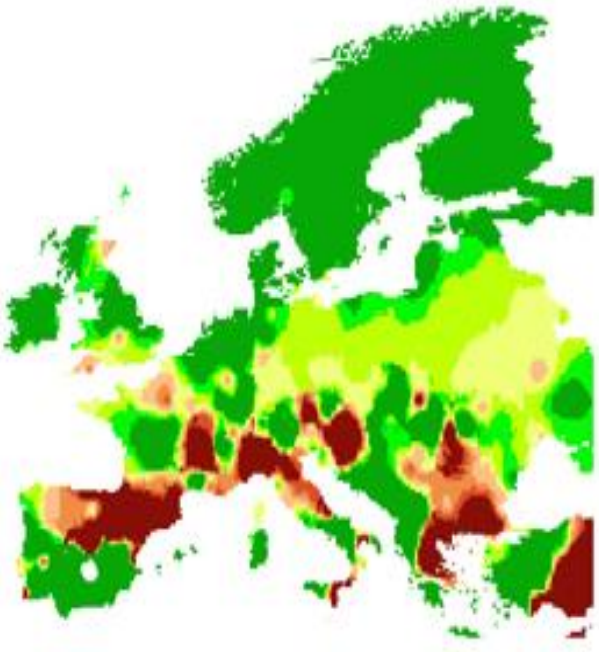
…and as a much needed new source of innovation and economic growth in many countries

A growing global population



Growing more food with less land

Agriculture: crop yield changes in 2025 scenario



Agriculture: crop yield changes (%), compared to the 1961-1990 period

	By 2025	*By 2080 with + 2.5ºC*	*By 2080 with + 5.4ºC*
Northerm Europe	***62***	***37***	***52***
UK and Ireland	***20***	***-9***	***19***
Central Europe North	***16***	***-1***	***-8***
Central Europe South	***7***	***5***	***-3***
Southerm Europe	***15***	***0***	***-27***
EU	***17***	***3***	***-10***

Source: JRC Climate Change impacts in Europe. PESETA research project. 2009

Food from the ocean

World capture fisheries and aquaculture production

Million tonnes

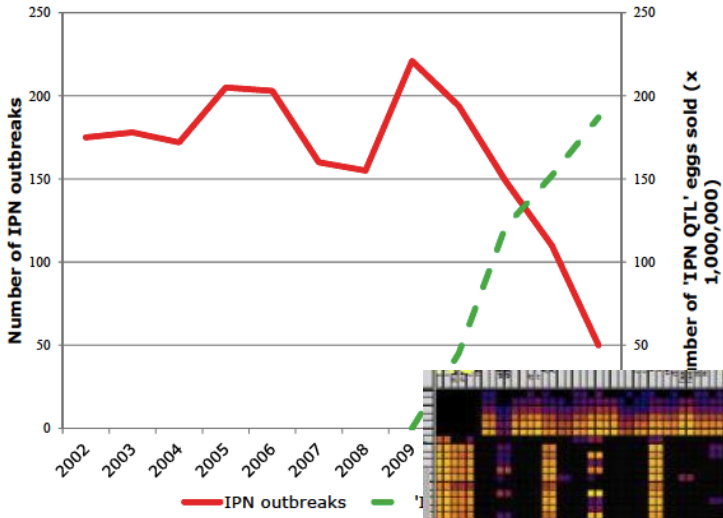
160
140
120
100
80
60
40
20
0

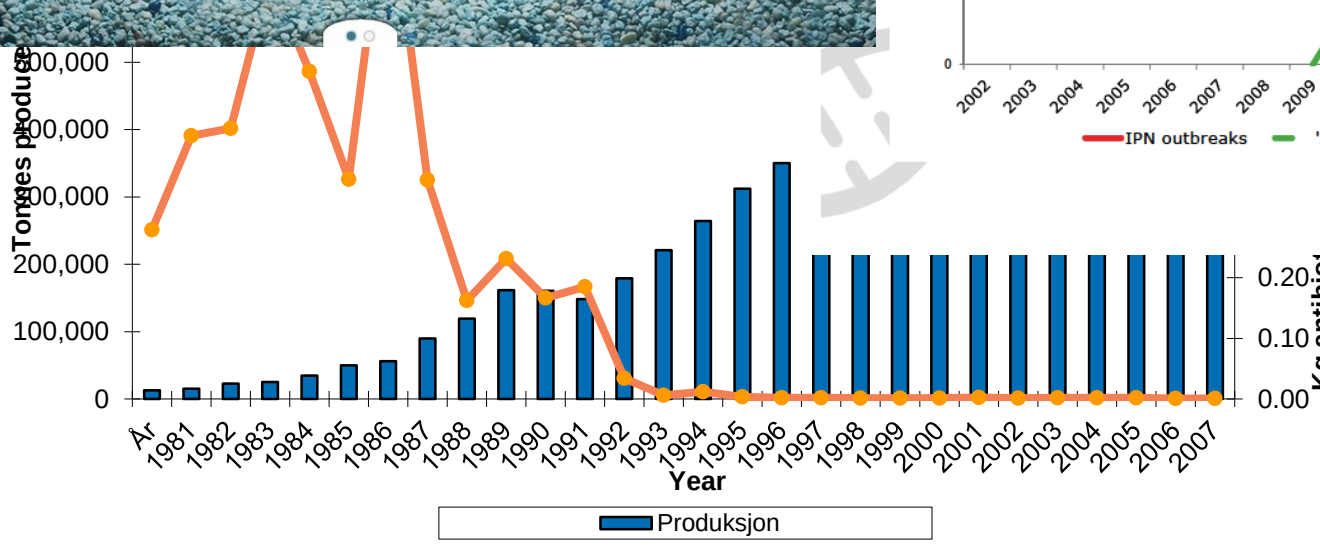
Aquaculture production
Capture production

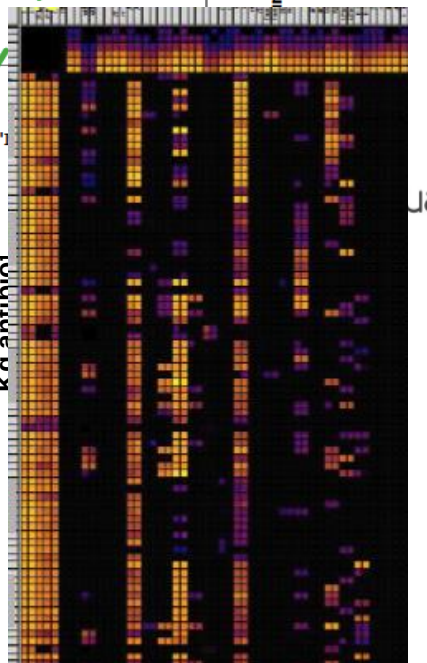
50 55 60 65 70 75 80 85 90 95 00 05 10

Molecular Aquaculture

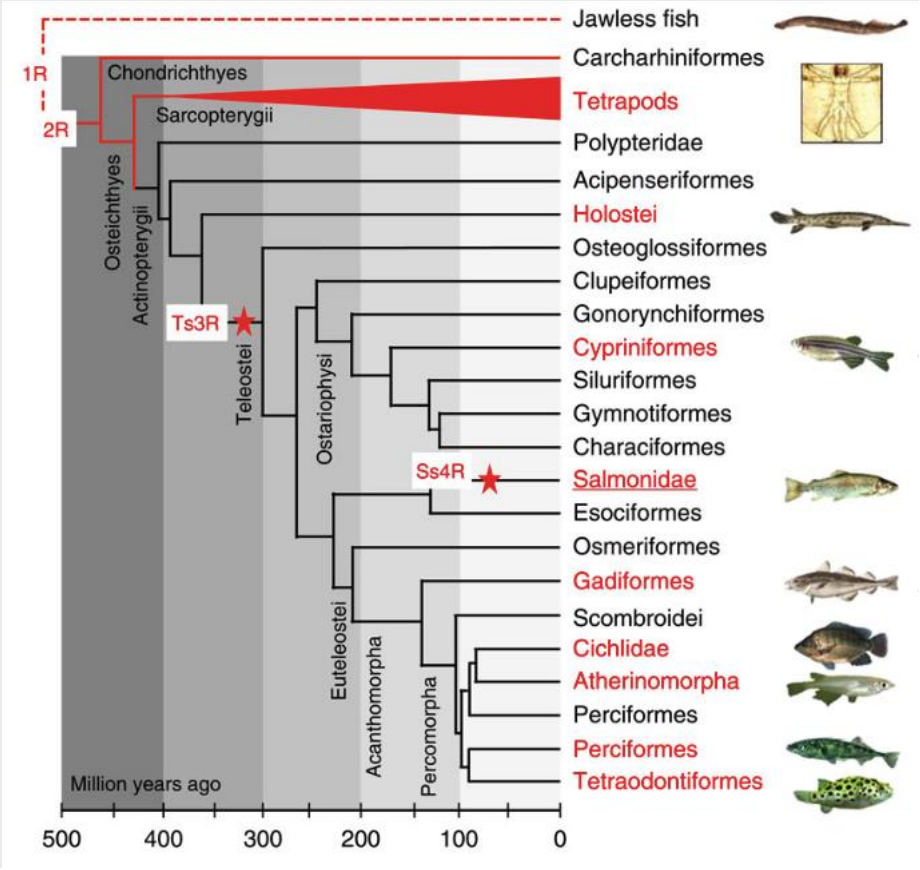
The QTL has lead to a decrease in the number of IPN outbreaks in Norway







Genomics



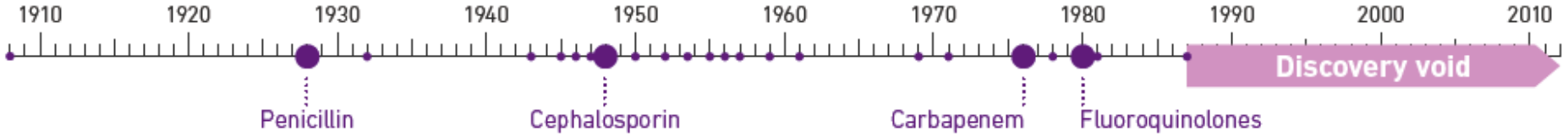
- Improved understanding
  - life cycle, nutritional requirements, disease susceptibilities
- Development of improved feeds
- Development of new aquaculture stocks
- New inputs for marine biotechnology
- Etc.

Davidson, et al., 2010, Berthelot et al., 2014

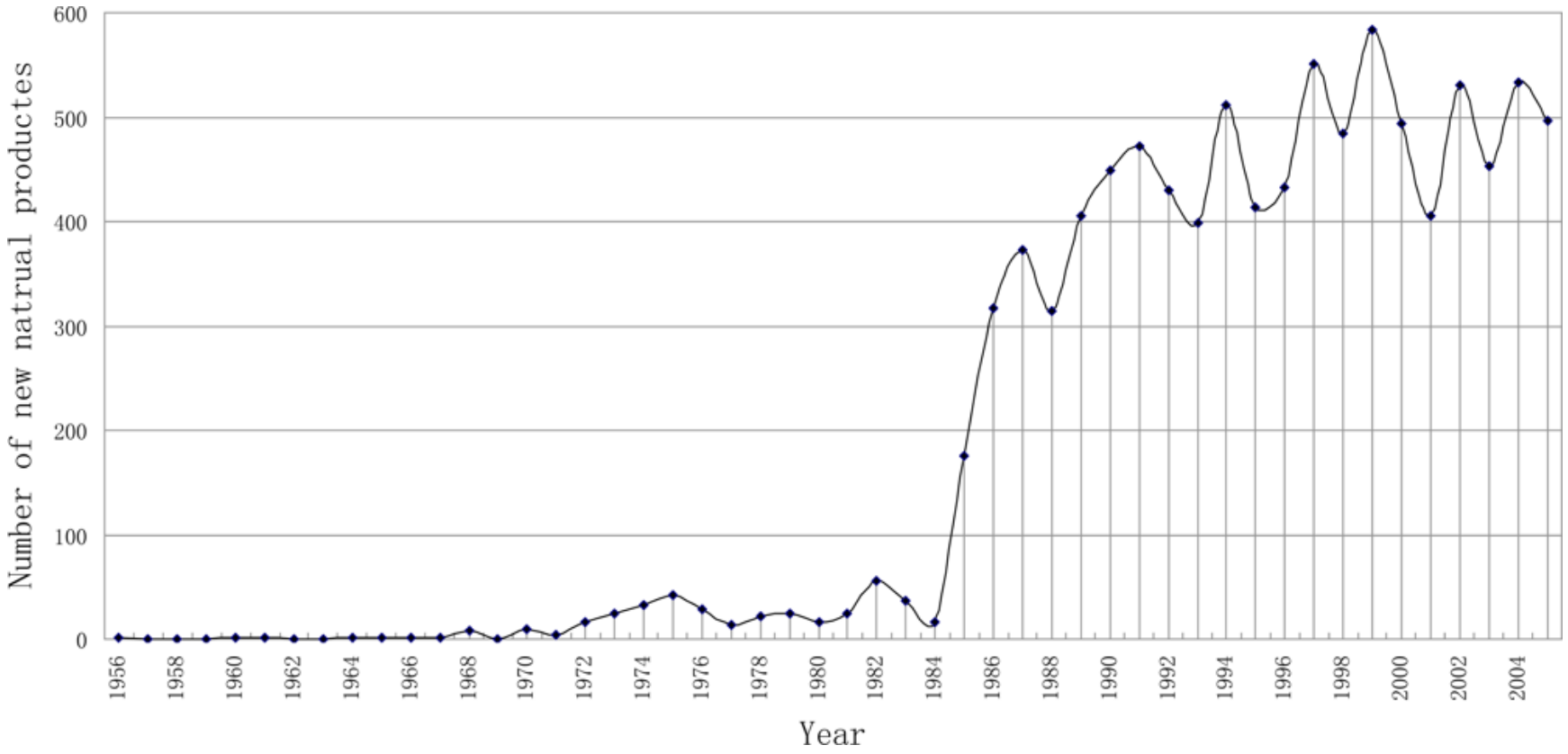
A need for new drugs

- A shrinking drug development pipeline
- Rise in antimicrobial resistance (AMR)
- Reduced ability to manage disease and infectious disease
- Threatening population health on a global level

Over the last 30 years, no major new types of antibiotics have been developed



Marine natural product discovery



Hu *et al., Marine Drugs* **2011**, *9*(4), 514-525; doi:10.3390/md9040514

Global marine pharmaceutical pipeline (2012)

Antitumour
Antibacterial
Antifungal
Antiviral
Antimalarial
Antituberculosis
Antiprotozoal

FDA approved: 7

Clinical pipeline: 11

Preclinical pipeline: 1,458

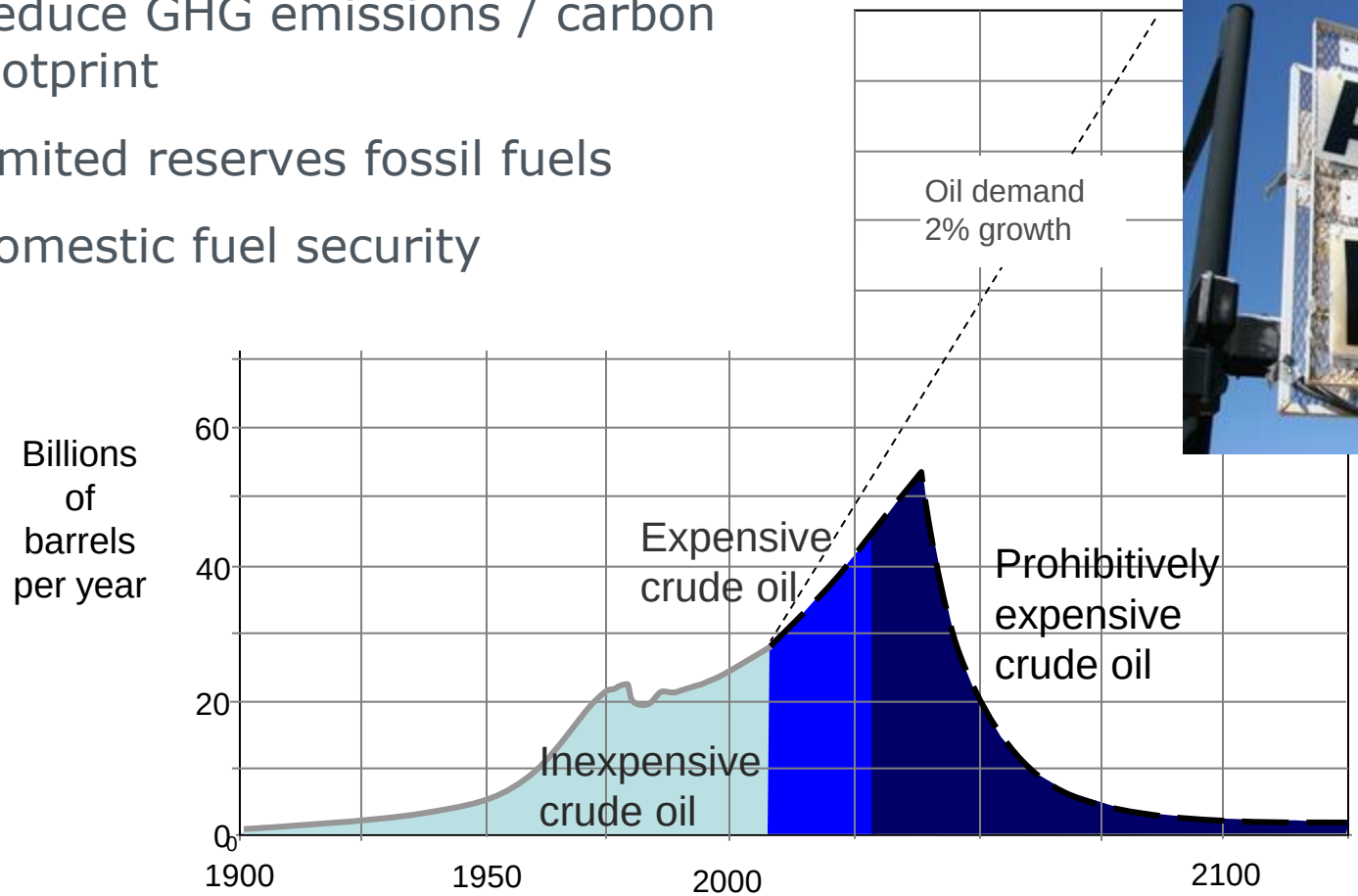
Chemistry marine natural products: 8,940

Anticoagulant
Cardiovascular
Anti-inflammatory
Immune system
Nervous system
Molecular targets
enzymes
receptors

Mayer (2012). OECD Marine Biotechnology Workshop, Vancouver, May 2012
Mayer et al. (2011). *Comparative Biochemistry and Physiology* Part C153, 191-222.

Energy security

- Reduce GHG emissions / carbon footprint
- Limited reserves fossil fuels
- Domestic fuel security



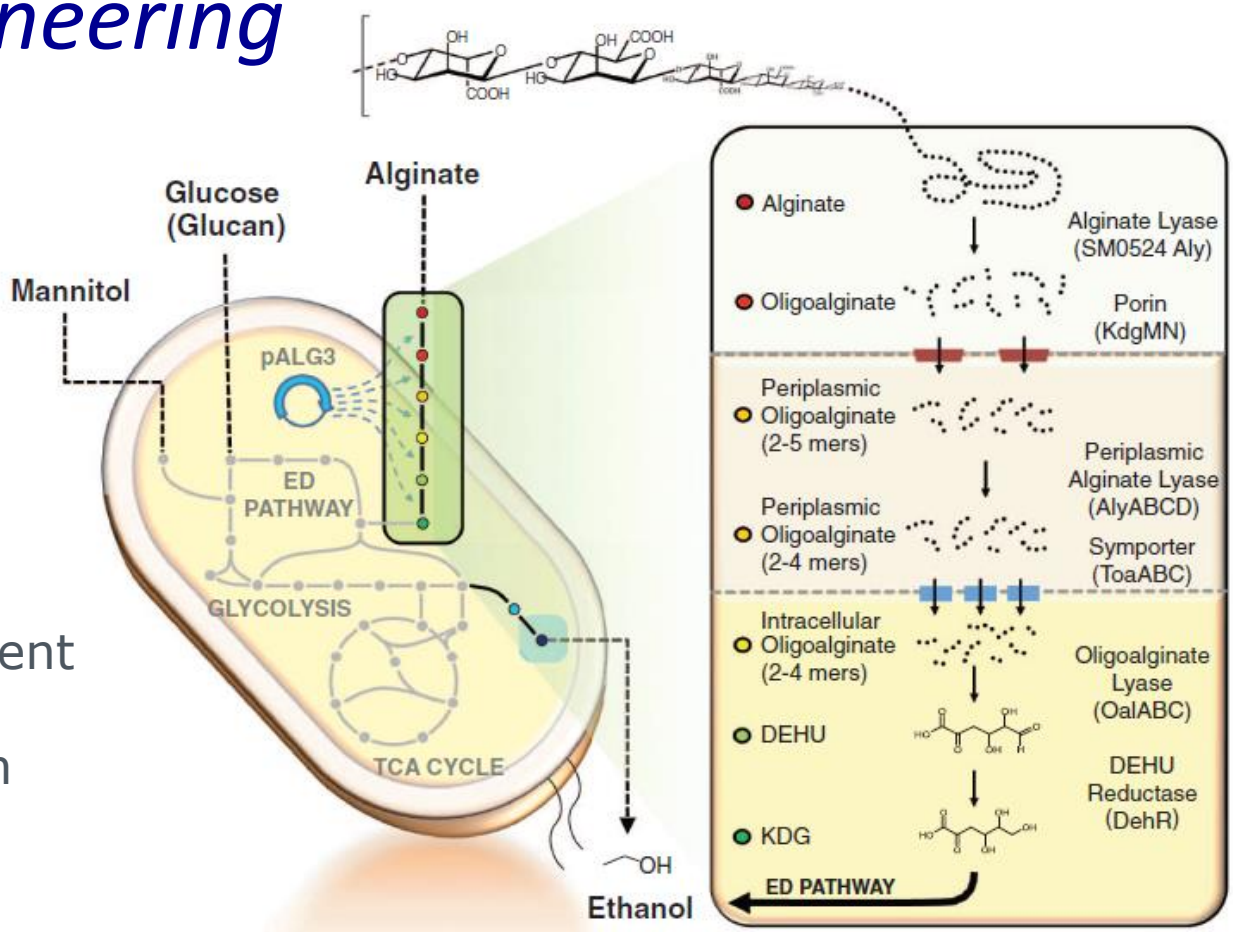
Algal biofuels

Crop	Oil yield [gallons (acre)$^{-1}$]
Corn	18
Cotton	35
Soybean	48
Mustard seed	61
Sunflower	102
Rapeseed	127
Jatropha	202
Oil palm	635
Algae	**10,000**

- Advantages over 1st & 2nd generation biofuels
- Potential in biofuels dwarfs all commodity chemicals
- Amenable biorefinery application

Microbial engineering

- Feedstock analysis
- Synthetic biology
- New strain development
- Extraction-conversion improvements



Bio Architecture Lab (BAL), Wargacki, *et al.,* 2012

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Biofuels from algae

cellana

Planet sustainability

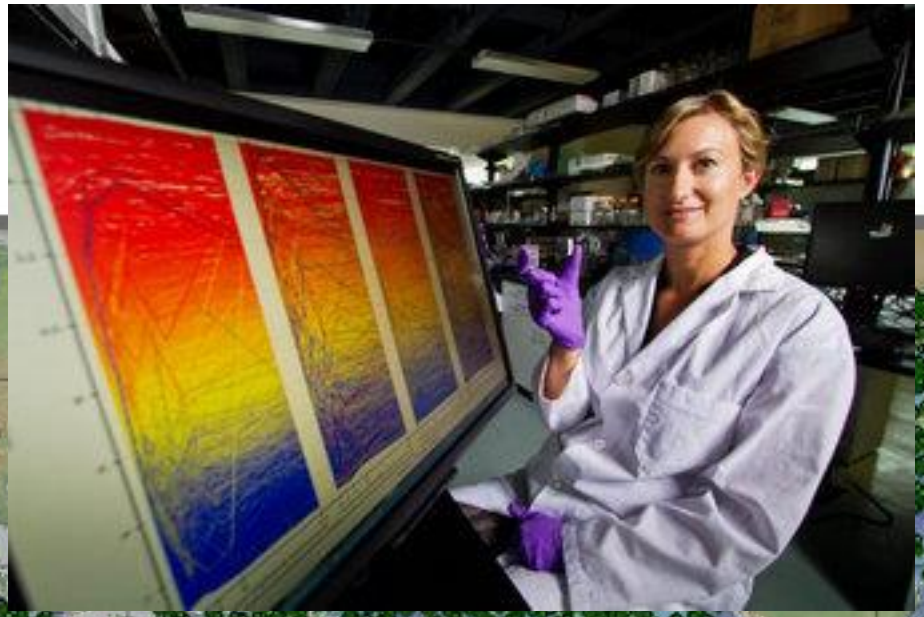
$33 trillion, 21 from oceans

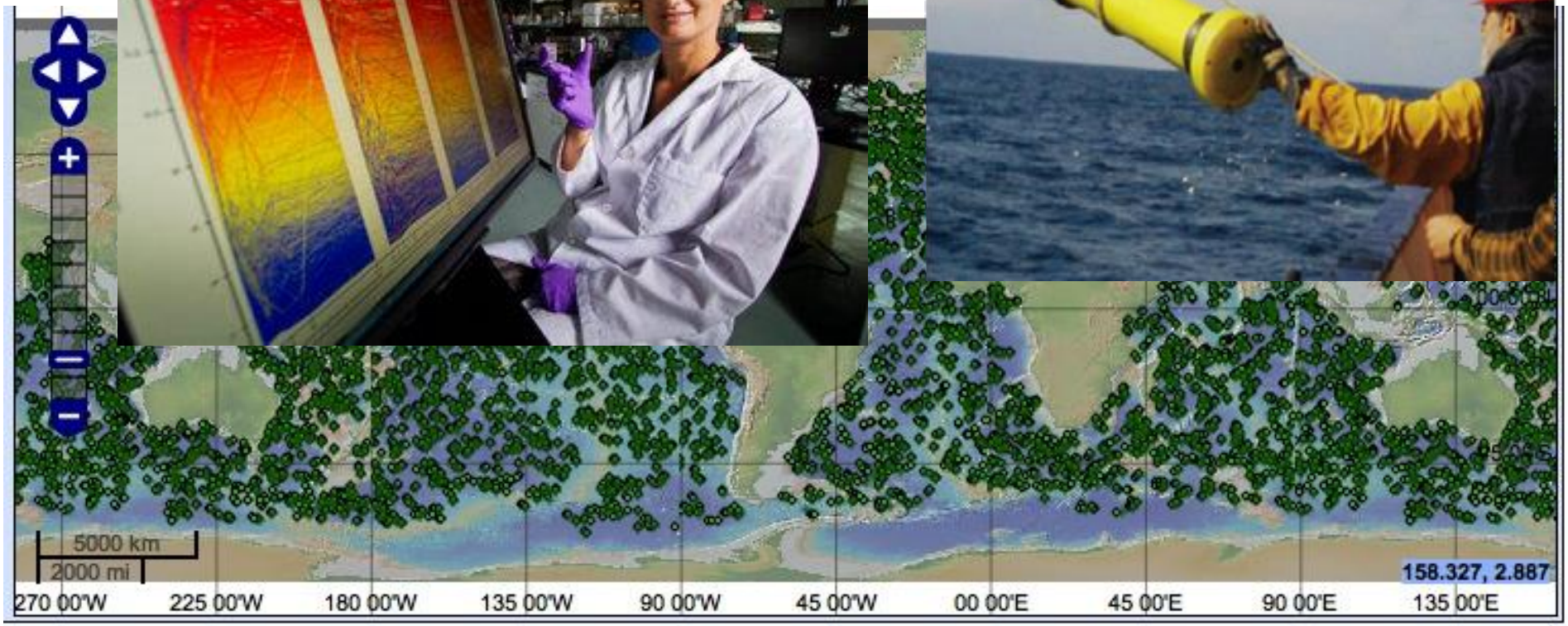
1. Gas regulation
2. Climate regulation
3. Disturbance regulation
4. Water regulation
5. Water supply
6. Erosion control
7. Soil formation
8. Nutrient cycling
9. Waste treatment
10. Pollination
11. Biological control
12. Habitat / Refugia
13. Food production
14. Raw materials
15. Genetic resources
16. Recreation
17. Cultural

Costanza et al. (1997)

Marine ecosystem pressures

Monitoring and biosensors





Bioremediation

Kill-Spill (FP7)

DFO

The potential is great….

The **global market** for marine biotechnology is projected to reach **US $4.6 billion** (2017) with growth rates of ~**4.0% per year.**

…but is by no means assured.

Marine Biotechnology today

- Most activity confined to EEZ / coastline
- Little deep-sea/open ocean development
- Commercial activity driven by existing companies or biotechnology companies (eg. Aquaculture, drug companies)
- Few *marine* biotechnology SMEs
- Commercial successes are production or extraction-based

Marine Biotechnology today

today 3 years 5 years 10 years 20 years 30 years

Access to market

Aquaculture

Biofuels

Novel drugs

Secondary metabolites, novel bioactives for a range of applications

Cosmetics

Food additives

Industrial biomaterials

How can the renaissance lead to a blue revolution?

1. Investment challenges

- Lack of funds / incentives for investment
- Biggest players are existing, established companies
- Capital hurdle for SMEs* (need access to platforms)

Different drivers

- ➢ Not enough ‘success’ stories from the renaissance yet
- ➢ Lack of measures and indicators
    - Allocation, Analysis, Advocacy, Accountability

2. R&D infrastructure challenges
(*research-enabling & industry-enabling)*

- Need to develop appropriate RI to support marine-specific capabilities and needs
    - (e.g. Vessels, ocean monitoring, collection, model organisms)
- Take advantage of other biotechnology RI
    - (e.g. genomics platforms, big data analytics, synthetic biology, nanotechnology)

➢ Standardization, integration, harmonization

3. Monitoring / Governance

protection and utilization

- Existing frameworks for ‘access and benefits’ *beyond* EEZ
- Coordination of marine resource ‘activities’ *within* EEZs (balancing productivity with sustainability) – ’regional’

➢ Need for development of tools to monitor impact on ocean

➢ Need for monitoring frameworks at regional and International level

4. Impacting global needs?

- Global challenges cannot be addressed by developed countries along.
- ➢ Technology transfer /capacity building to allow for development of local solutions in
  - Aquaculture / food production
  - Integrated biorefineries

Thank you!

Rachael Ritchie
rritchie@genomebc.ca