Scotland: A Hydro Nation

Diane Duncan

Head of Low Carbon (water and clean tech

HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean

Climate Change

Low Carbon and Circular Economy

Water Sector Growth

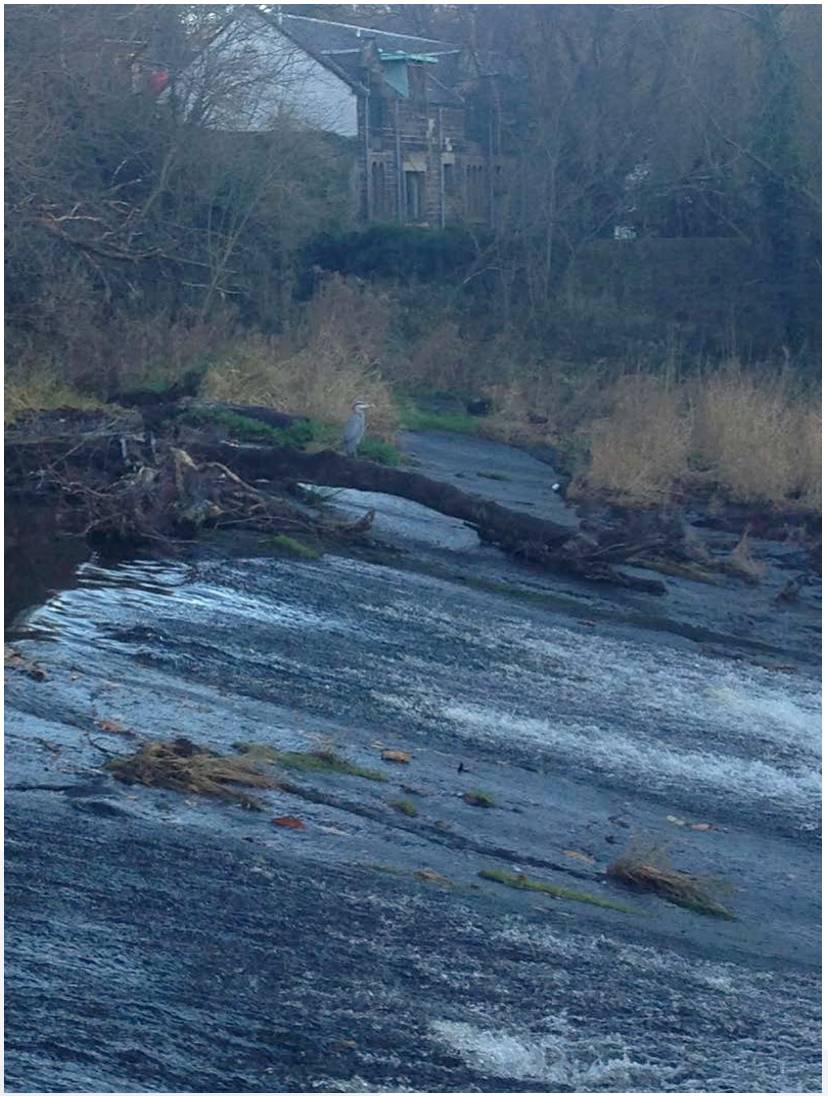
Key Sector Support

Scotland: A Low Carbon and Hydro Nation

1. Climate Change Act Scotland 2009

2. Water Resources Bill Scotland 2013 - Enterprise Agencies tasked to develop £ of **ALL** Scotland's Water Assets - SME/Academia

3. Zero Waste agenda evolving into Circular Economy



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Highlands and Islands Enterprise Region

North and West of Scotland

90 inhabited islands

9 out of 10 water processing plants

10% of Scotland's population

2000 private water supplies

160,000 septic tanks

Water quality key to inward investment & sectors

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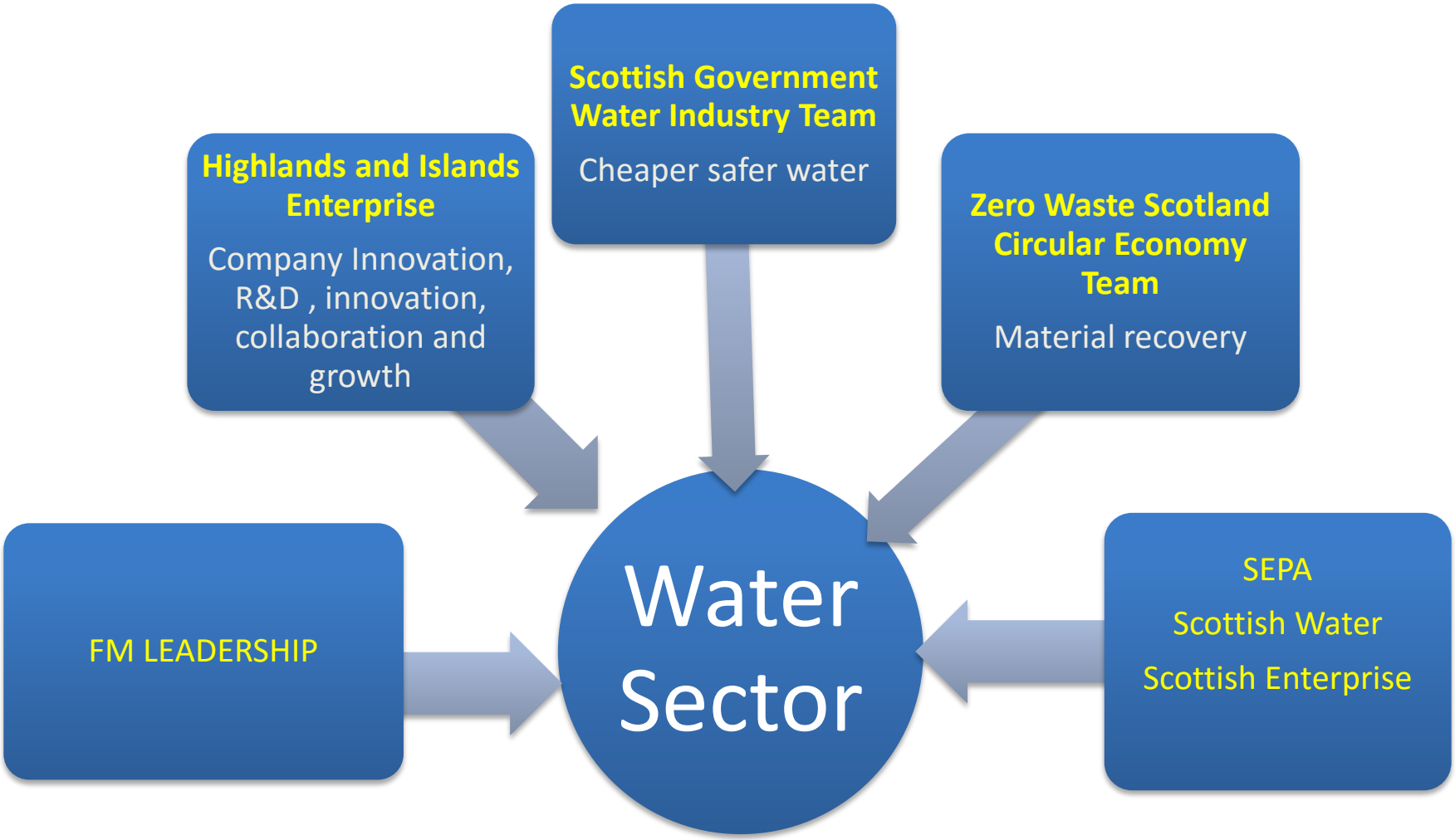
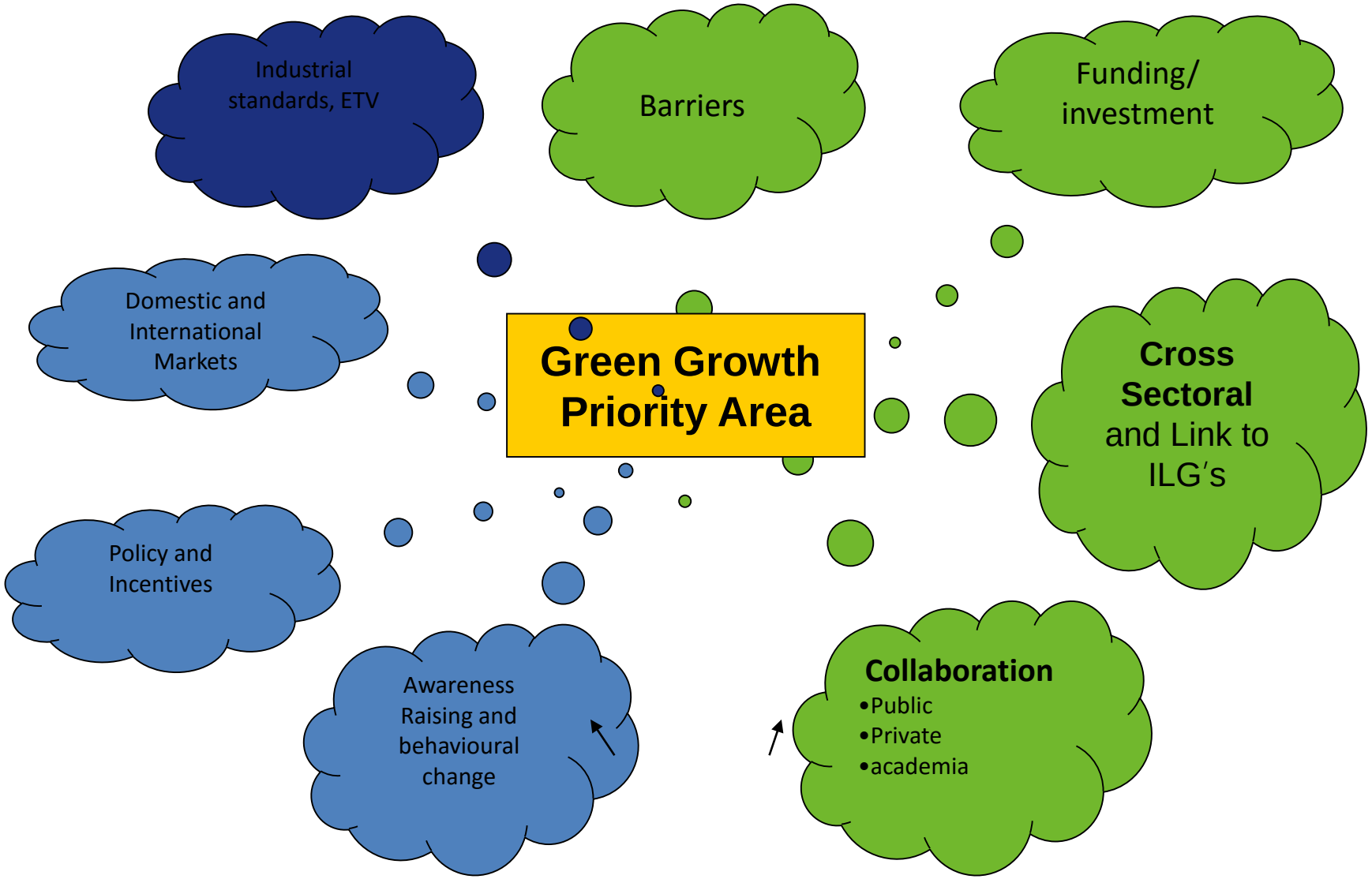
Scotland's Green Growth Agenda: Water Work Stream



Scotland's Green Growth – The Inhibitors



INDUSTRY SURVEY

OPPORTUNITIES AND THREATS

Phosphorus

- Potential opportunity for income
- Address risk from volatile prices/supply
- Rural Water services – (160K septic tanks rural Scotland)
- Halting development in urban and rural areas
- Regulatory pressures - increasing levels and risk to biodiversity from eutrophication

Priority Substances

- Water Framework Directive – NO sustainable technologies
- Not just water industry, agritech, aquaculture, personal care and pharma
- Most toxic, neurologically damaging and carcinogenic substances impacting on human health and biodiversity
- Not a sustainable or circular economy if present in environment

International Issue : International Market

Bangladesh – Arsenic,and hromium

Bangladesh – Textile dyes

Eutrophication and coastal dead zones

Flushed down lavatories throughout the globe

Innovate UK's
SBRI (Small Business Research Initiative)
Pre Procurement Innovation Call
(Public Sector Collaboration)

Funders: Scottish Government, Zero Waste Scotland, Highlands and Islands Enterprise

How can the water and waste-water sector improve its effectiveness and efficiency in recovering and/or removing phosphorus and/or priority substances from water, waste water and sludge for potential commercial reuse and, as appropriate to meet the demands of the EU Water Framework Directive and support a Circular Economy in Scotland?

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Cross Department Innovation Call

- **Phase 1 Feasibility Studies**

  (7 funded up to 40K)

  40 entries received (47)

- **Phase 2 – up to 4 prototypes and testing £100K**

  Live site testing to be carried out in Scotland 2016

Contract Winners (1)

Sustainable Water Company, Edinburgh - **Iron ochre pellets produced from abandoned mineworkings. P recovery in WW streams and used for fertiliser**

New Gen Biogas, Plymouth - **biological phosphate using microbes. EBPR have limited success, - NBG high throughput AD to increase microbial density and optimisation**

Pennog, Wales **Phosphorus Capture and Recycle in a Plant Bio Stimulant**

re-directing biodegradable industrial waste streams into recovery of P from outflow streams from WWT/water courses to supplement natural plan bio stimulant products

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Contract Winners (2)

De Monteford University: UNMWCAT UV and microwave assisted catalysts for destruction of PS x5 times effectiveness of iron catalysts

Brathadair, Edinburgh: Recovery of P from pot ale. Extraction of seed struvite crystals from pot ale (Aberdeen University and James Hutton Institute, Aberdeen – at Hall 7

JFI, Northern Ireland: Low Cost Nano adsorbents for Phosphate and priority substances for WWT

Uist Asco: (HIE region) Eutrophication from nutrient elevation in water courses from fertiliser. Residue from seaweed fertiliser converted to absorbant with biomass from water courses used as slow release fertiliser

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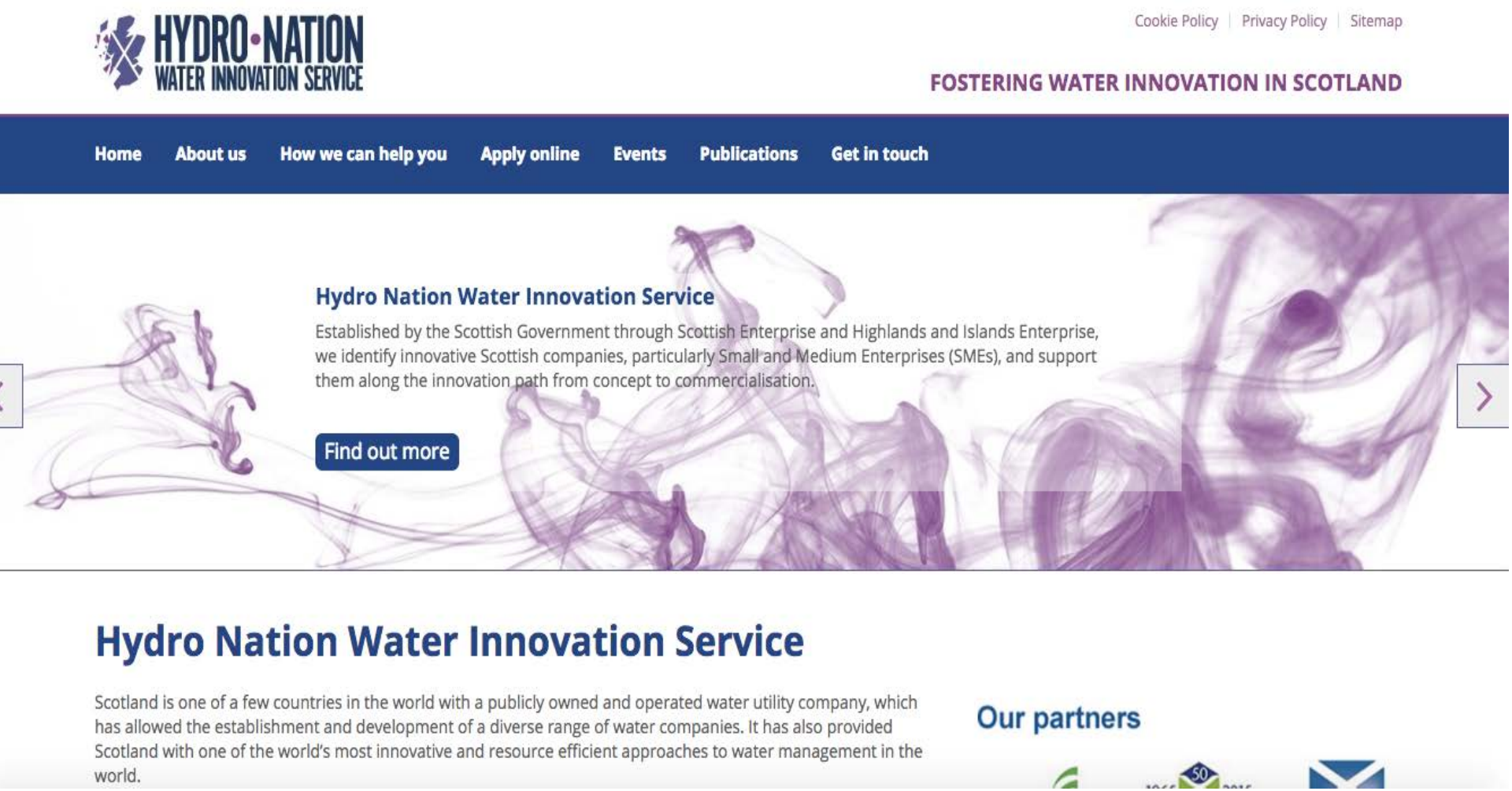
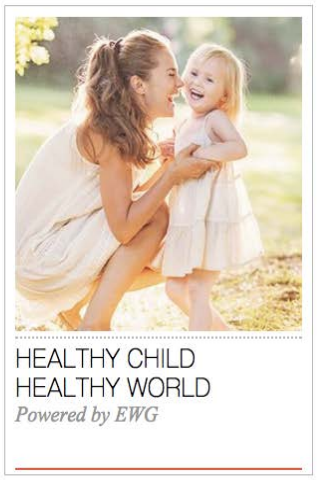
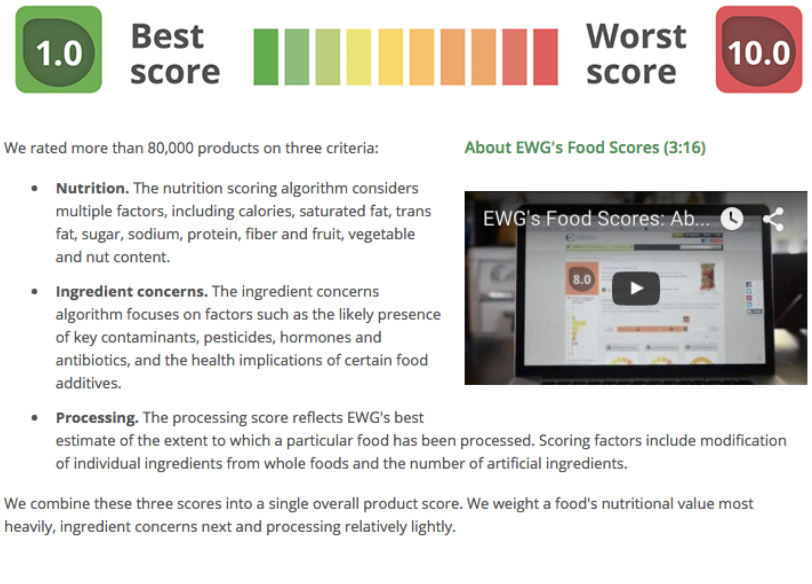
Hydro Nation Water Innovation Service



Future activity

- Big data
- Hakathons
- Apps /Citizen Science
- Future SBRI /PPC





2016-2017 calls in support of PCP and PPI

2016 (~40 M€)

- PCP actions
  - E-health: 18 M€ (PM-12)
  - ICT based solutions for any area of public interest: 4 M€ (ICT-34)
  - Earth observation: 3 M€ (EO-2)
- PPI actions
  - ICTs Ageing: 10,5M€ (PM-13)
- CSA actions
  - Urban transport deployment: 2M€ (MG-4.4)
  - Climate – environment-raw materials - resource efficiency: part of larger call (SC5-27)
  - Civil protection: 1,5M€ (2-DRS)

2017 (~84 M€)

- PCP actions
  - Robotics smart cities: 7 M€ (ICT-27(d))
  - Soil decontamination: 5 M€ (SC5-26)
  - Broadband coms security: 10 M€ (4-DRS)
  - Forensics: 10 M€ (9-FCT)
  - Border control: 10 M€ (13-BES)
- PPI actions
  - E-health standards: 8,26 M€ (PM-19)
  - Supercomputing: 26 M€ (EINFRA-21)
  - Energy efficiency: part of larger call (EE-19)
- CSA actions
  - Competence centers & procurer networks any area preparing

Sustainable circular economies ……. we have a lot of work to do!

Thank You

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Phosphorous & Priority Substances SBRI Competition

Highlands and Islands Enterprise
Scottish Government's Water Industry Team
and Zero Waste Scotland

Joel Ferguson & Tamsin Woods
JFI Ltd

SBRI Government challenges. Ideas from business. Innovative solutions.

Scottish Enterprise

SEPA Scottish Environment Protection Agency

Scottish Water Always serving Scotland

Highlands & Islands ENTERPRISE

ZERO WASTE SCOTLAND

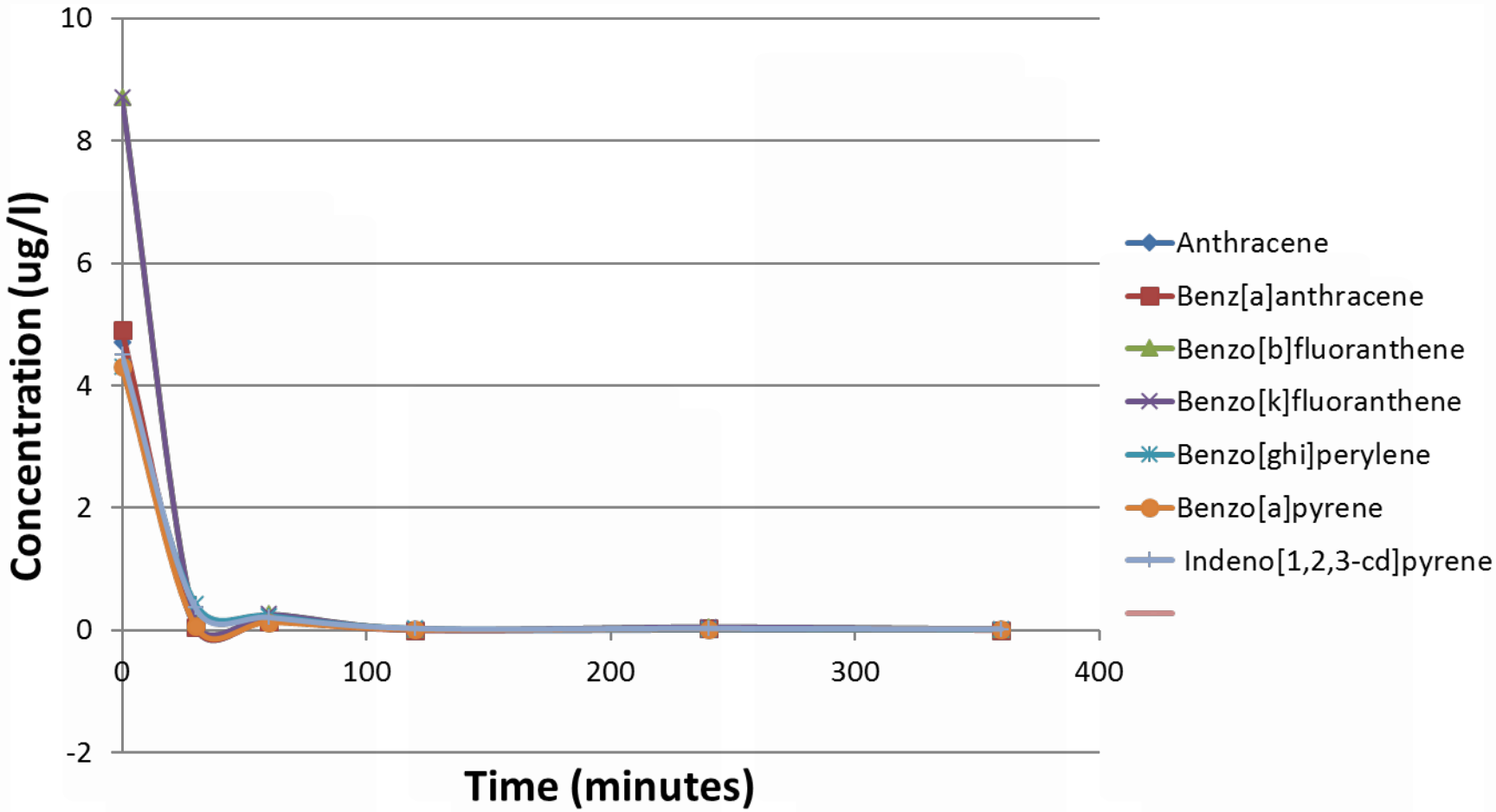
Background

- Low cost nano-materials with scalable manufacture
- Remove Priority Substances from wastewater
  and also phosphorous
- Enhance existing WWTW or additional tertiary treatment
- Readily removed after treatment
- Innovation Voucher late 2014

Approach

- Awarded SBRI funding 2015 + established project team
- Based at Nano-Technology Institute, Ulster University
- Development of methods
- Scalable production of materials
- Jar testing initially with phosphates
- PS testing, initially with PAHs
- Efficacy in removal and recovery
- Extend to broader PS list

PAH Kinetics Removal Kinetics



Priority Substances to be tested

Compound	LOD (ug/l)	Residual
Endosulfan (Alpha-Endosulfan)	0.01	**<0.01**
Hexachlorocyclohexane (Gamma-	0.01	**<0.01**
Hexachlorobenzene	10	
Hexachlorobutadiene	10	
Trichlorobenzenes (1,2,4-	10	
Pentachlorobenzene	10	
Atrazine	0.01	
Simazine	0.01	
Diuron	1	
Isoproturon	1	
Benzene	1	**<1**
1,2-Dichloroethane	1	**<1**
Dichloromethane	50	**<50**
Trichloromethane	1	
Fluoroanthene	10	
Anthracene	10	

Compound	LOD (ug/l)	Residual
Brominated Diphenylethers	10	
Di(2-ethylhexyl)phthalate(DEHP)	10	
Naphthalene	10	
Polyaromatic Hydrocarbons	10	
(Benzo(a)pyrene)	10	
(Benzo(b)fluoranthene)	10	
(Benzo(g,h,i)perylene)	10	
(Benzo(k)fluoranthene)	10	
(Indeno(1,2,3-cd)pyrene)	10	
Pentachlorophenol	10	

Alachlor
Chlorfenvinphos
C10-13-chloroalkanes
Nonylphenols (4-(para)-
(Tributyltin-Cation)
Chlorpyrifos
Octylphenol (Para-tert.
Trifluralin

Findings so far . . .

- Scalable manufacture achieved
- Effective PAH removal at low product dose (approx. 10mg/l)
- Contact time of 30 minutes
- Tested as a tertiary treatment
- Fully removed by settlement/flotation
- Also removes phosphates (<0.05mg/l)

Next Steps

- Extend range of PS tested
- Test compatibility with biological treatment
- Refine costs
- Optimise product & scale–up production
- Regulation & testing (E.g. REACH)
- Demonstration at pilot scale
  - Assist process optimisation & separate tertiary treatment

Sources of PS for trials & analytical testing?

Wastewaters with PS to evaluate?

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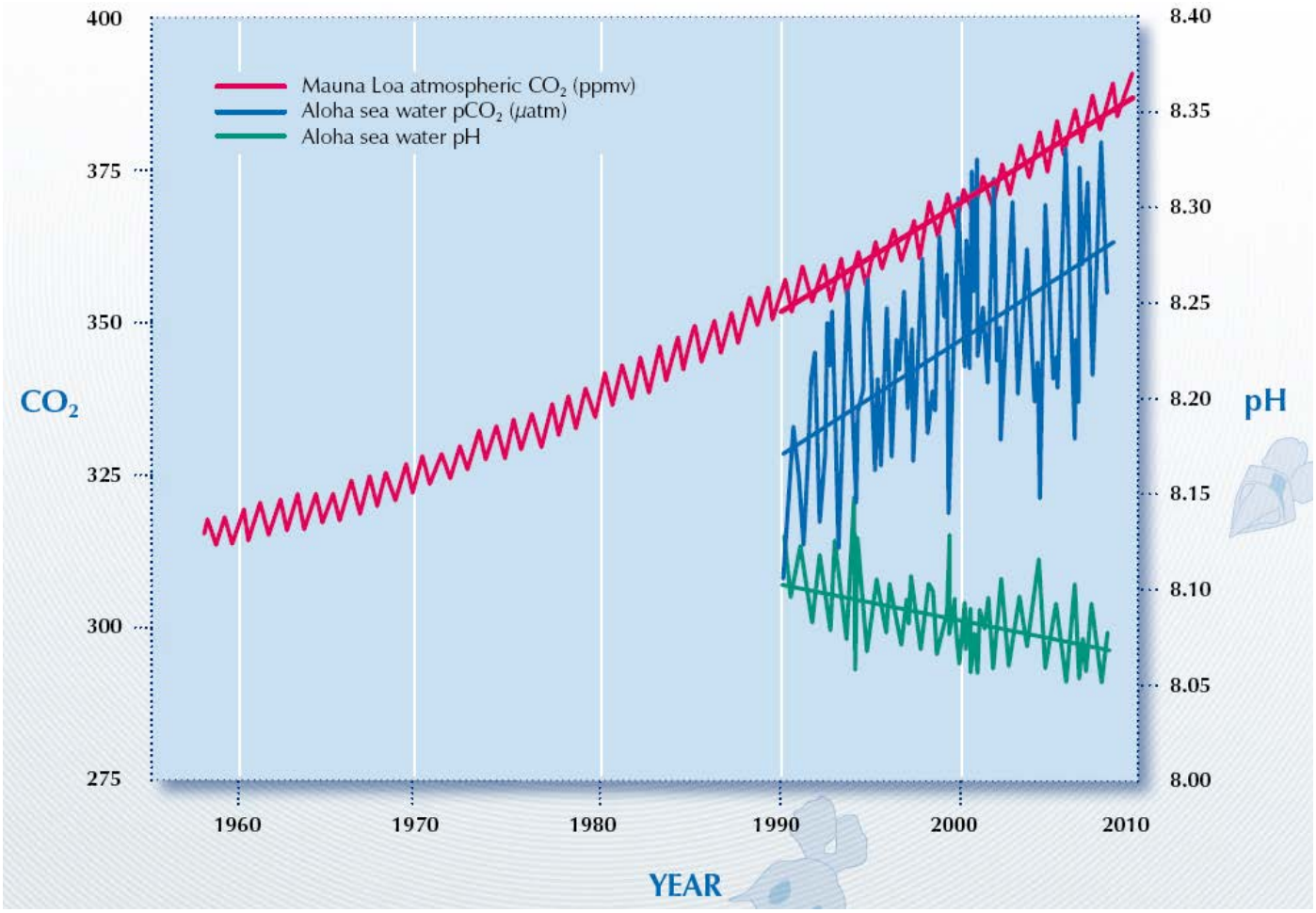
Ocean acidification alters the toxicity responses of marine animals to metals and other pollutants.

Dr Ceri Lewis
University of Exeter
@CezzaLew

The ocean is changing at an unprecedented rate.



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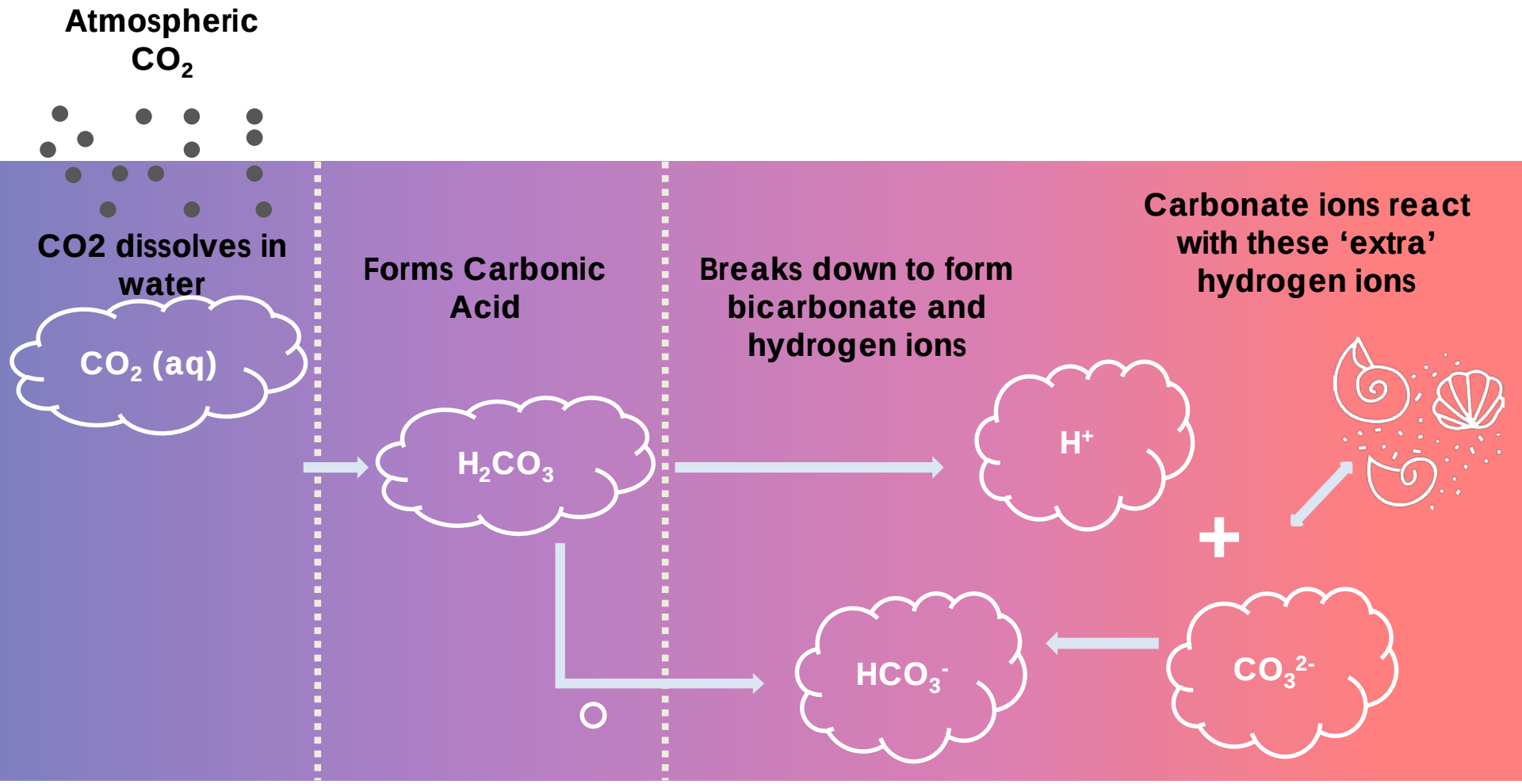
The ocean acidification process



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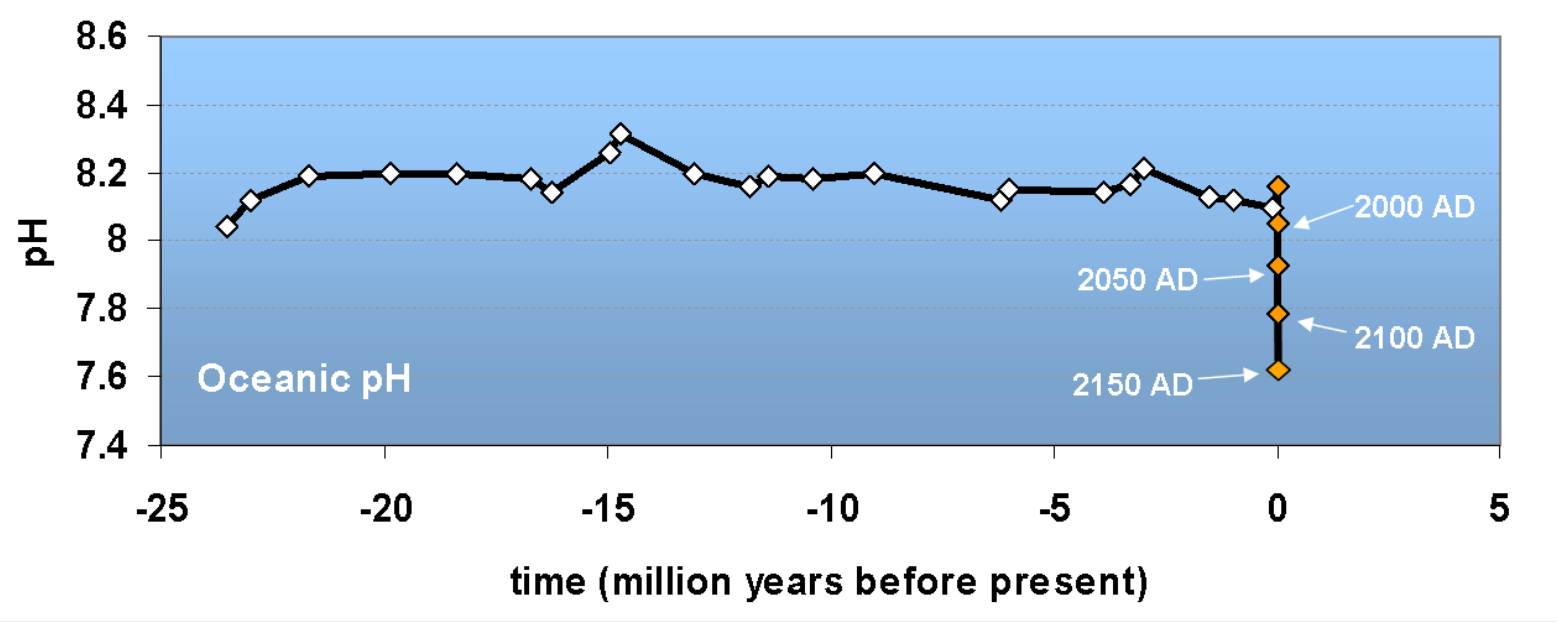
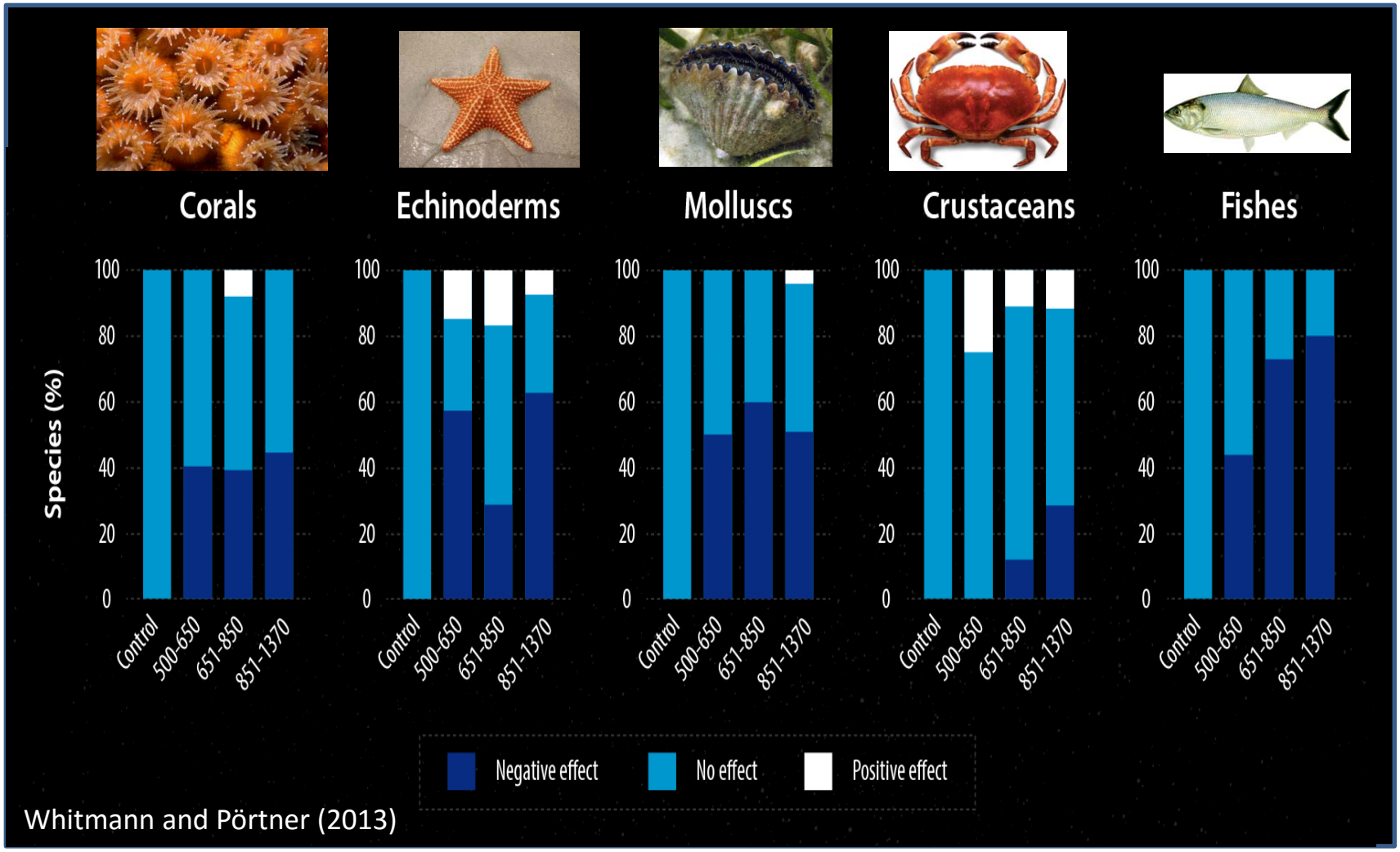
The **rate** of ocean acidification is perhaps more worrying than the degree of acidification



It is happening now, at a rate and to a level not experienced by marine organisms for ~ 300 MY

Honish et al (2012) Science: 335, 1058-1063

Over 50% benthic invertebrates and fish species studied to date at risk.



Whitmann and Pörtner (2013)

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Ocean acidification will alter metal behaviour

Copper toxicity changes with pH

Cu^{2+} | $CuOH^{-}$ $Cu(OH)_2$ | $Cu(CO3)_2^{2-}$ $CuHCO_3^{+}$ $CuCO_3$

More toxic — Less toxic

Seawater during high CO_2

- OA alters metal speciation
- Modelled to increase **115% for copper**

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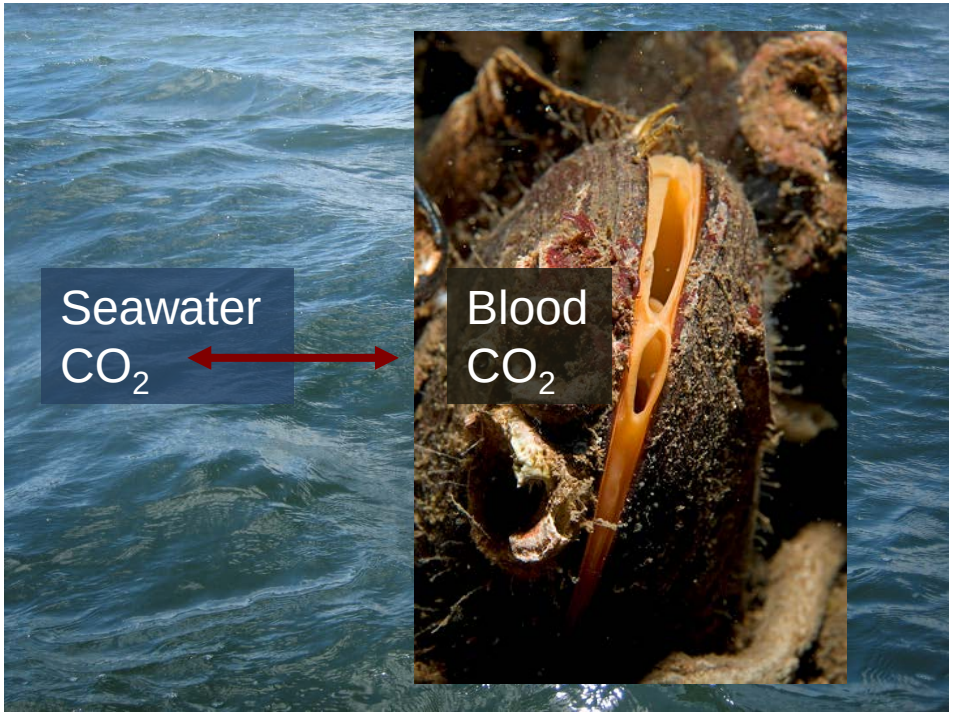
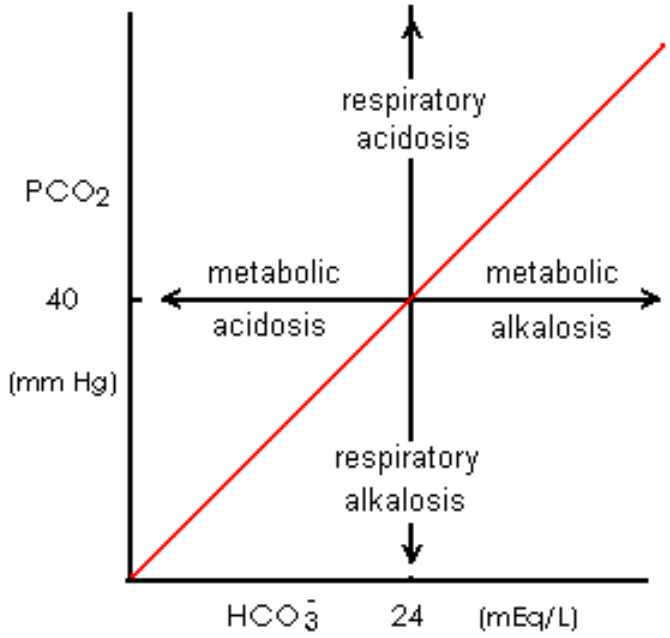
Acid-base response to OA

Respiration produces metabolic CO_2





$$CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow HCO_3^- + H^+$$

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Does near-future OA increase copper toxicity?

Mytilus edulis

Paracentrotus lividus

Carcinus maenas

8.1	7.7
8.1 + Cu	7.7 + Cu

0.01 µM copper

pH 8.14 = 436.4 µatm pCO_2

pH 7.71= 1373 µatm pCO_2

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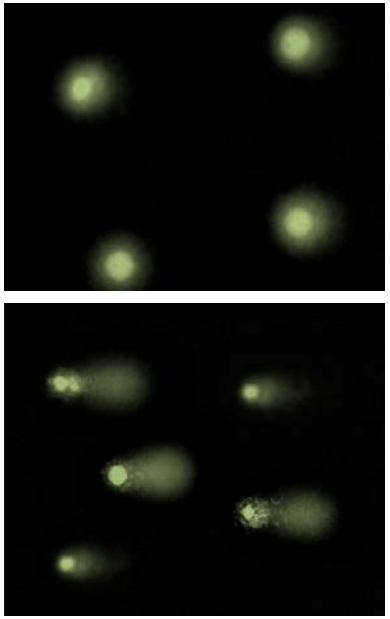
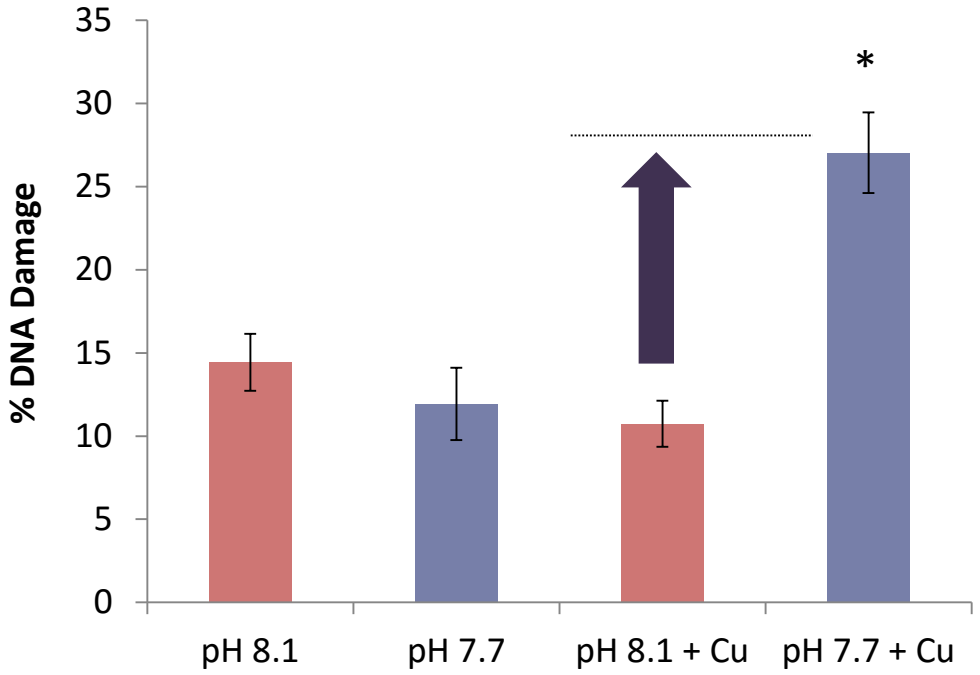
Ocean acidification increases toxicity in mussels



DNA damage induced by copper 90 % higher under OA



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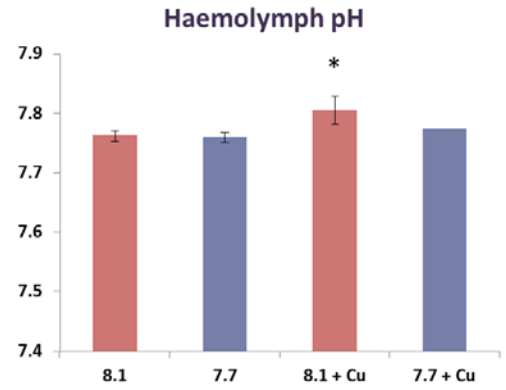
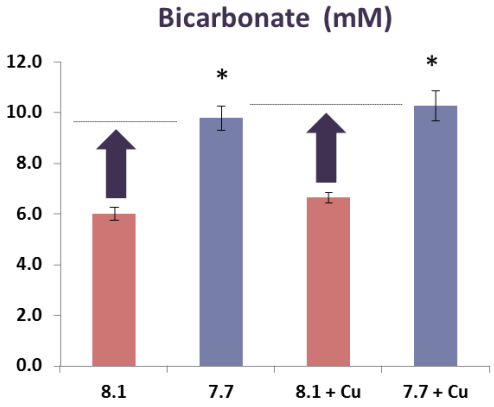
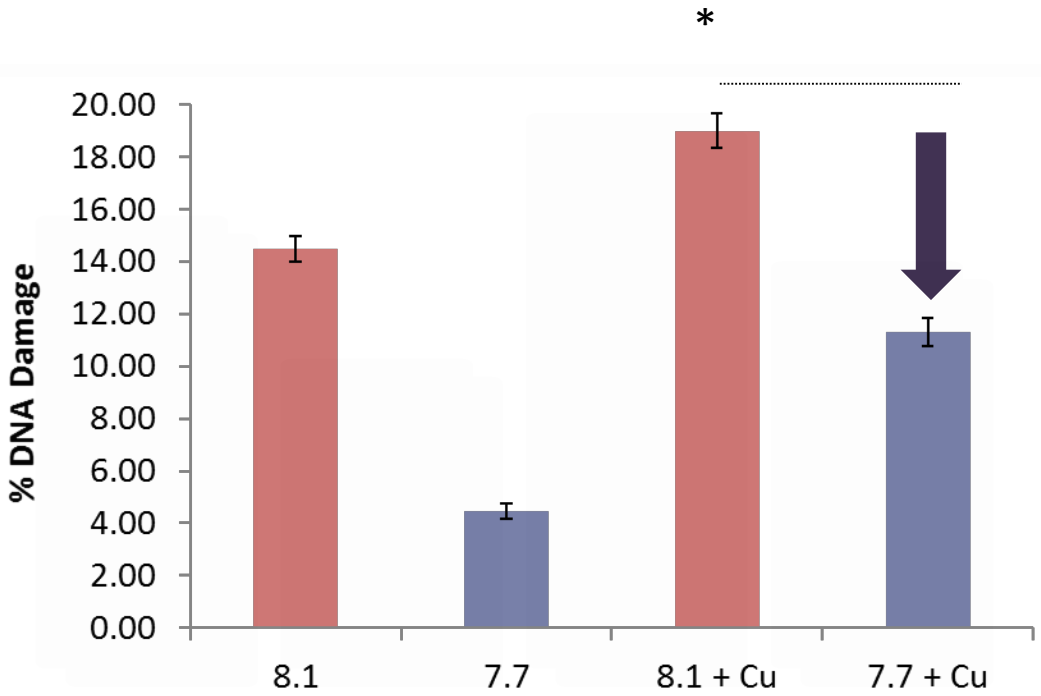
Ocean acidification decreases DNA damage in crabs





DNA damage induced by copper was 40 % **lower** under OA



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Physiology determines the interaction with OA

Gametes

✓ Additive increase in toxicity

Larvae

✓ Strong synergistic increase in toxicity in 2 species.

Adults

✓

✓

✓ Roberts et al., Global Change Biology (2013)

✗

✗

Possible relationship to acid-base regulation?

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- Steph Mangan
- Katie Elliot
- Amy Curry

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GoesFoundation.com

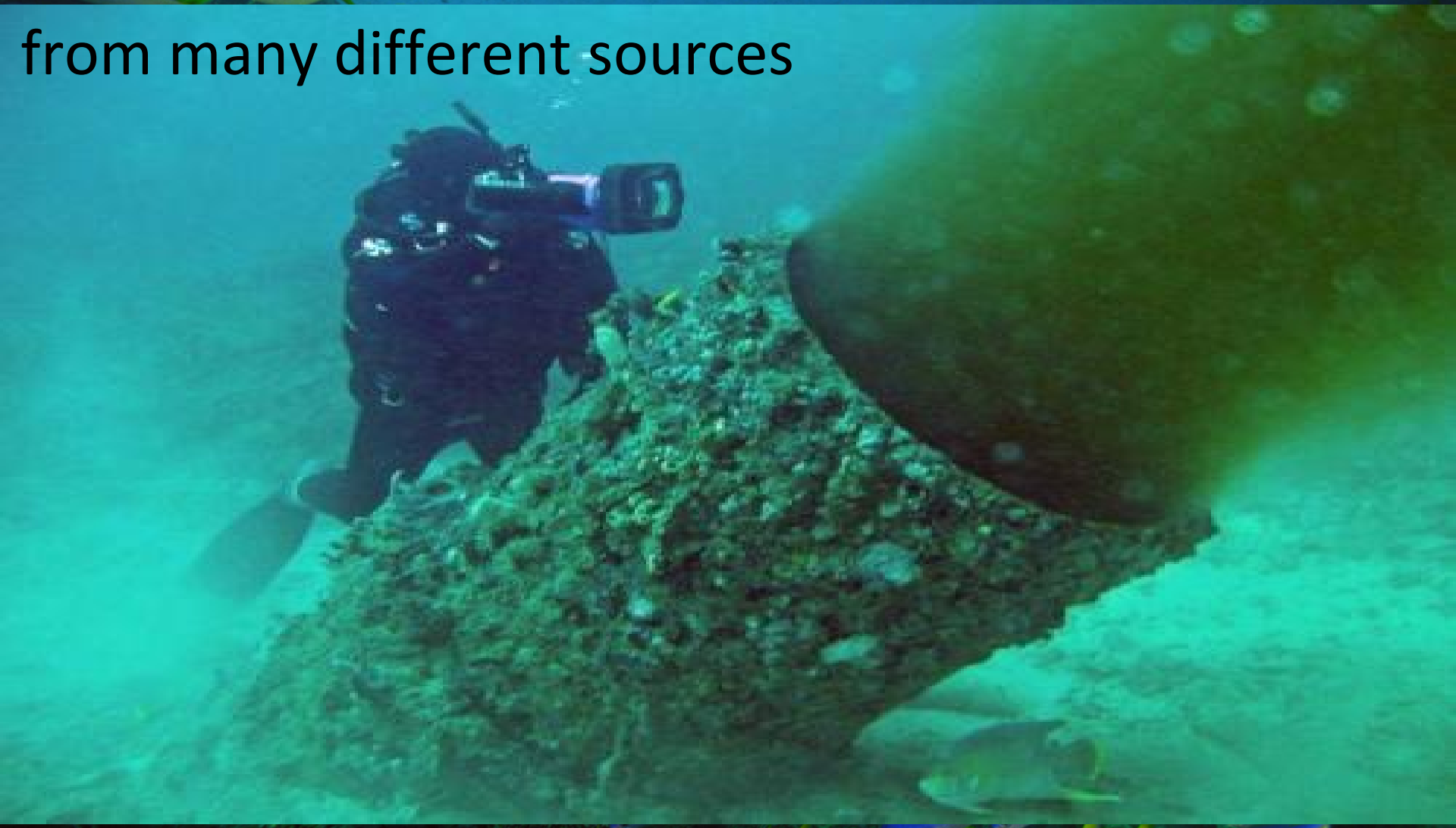
GLOBAL OCEANIC ENVIRONMENTAL SURVEY

Priority chemical pollution

Impact primary productivity, climate change


Billions of tonnes of Industrial waste enter rivers every year

from many different sources

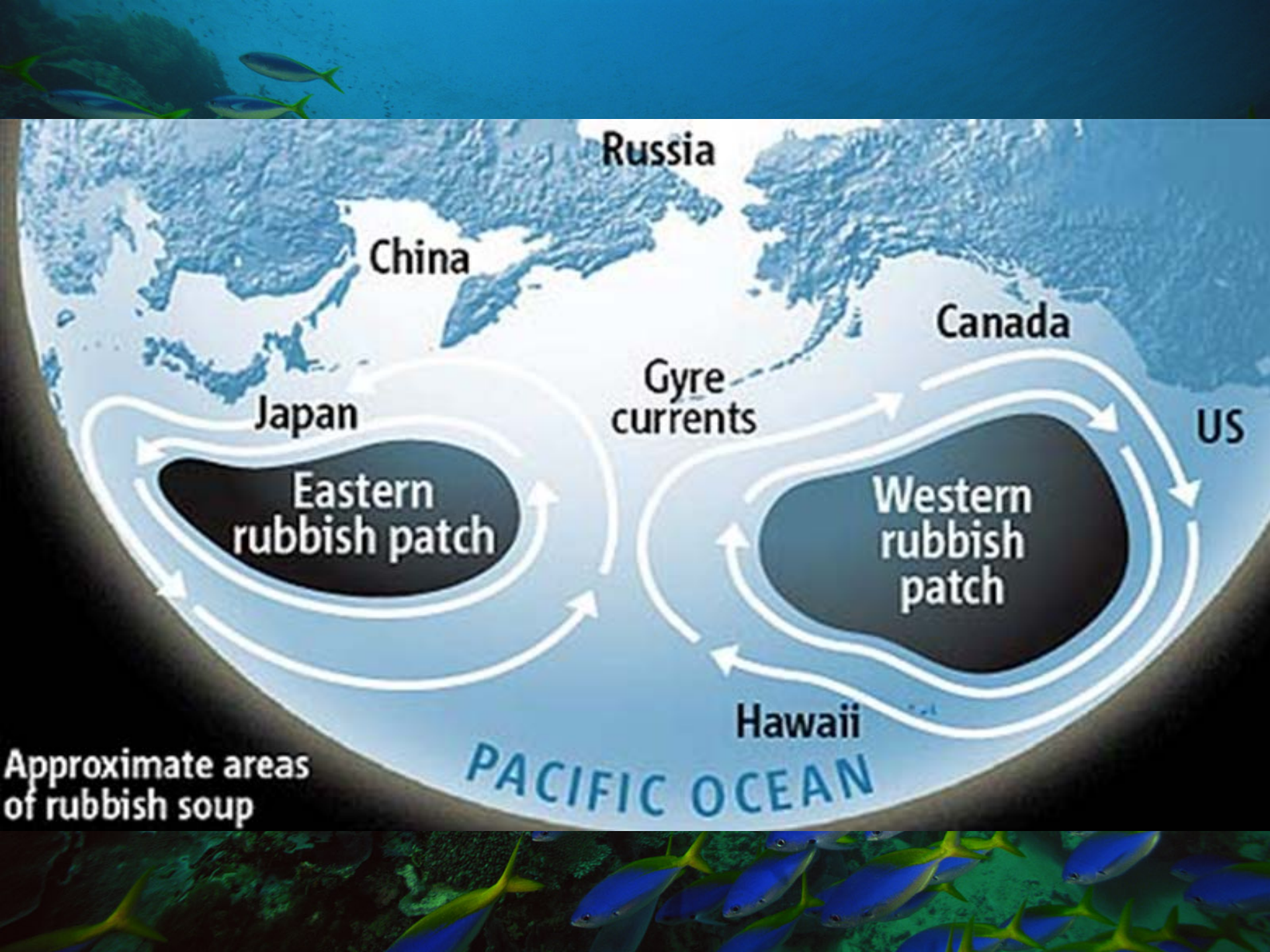



National Geographic
Barrow, Alaska


Haina, Dominican Republic. Photo Source: Eduardo Munoz


Helensburgh Scotland


It all eventually ends up in the oceans


Russia
China
Canada
Gyre currents
Japan
US
Eastern rubbish patch
Western rubbish patch
Hawaii
PACIFIC OCEAN
Approximate areas of rubbish soup

Mass of garbage is 6 times the mass of plankton in parts of the Pacific

46,000 pieces of plastic per square kilometer of the world's oceans, killing a million seabirds and 100,000 marine mammals each year

Just because you can't see it, it doesn't mean it isn't there

Priority chemicals impact on microscopic plankton (primary productivity)

Every fish, shrimp and living organism in the oceans will contain priority substances and micro-plastics that can concentrate priority chemicals.

Micro & nano plastics / particles concentrate the chemicals and deliver them to the organisms

Priority chemical concentrations

Ref MARBEF

1. ***PCB concentration in the North sea, 8.8 ng/l, concentration in biomass 600 to 1200 ng/g (dry weight)***
2. ***PCB concentration in Antarctic 1.2 ng/l, concentration in biomass is the same as North Sea 600 to 1200 ng/g (dry weight)***

3. **The above demonstrates that hydrophobic particles, including marine microbes will concentrate priority substances.**

Southern Ocean and Human health

Southern Oceans
"shark have levels of arsenic, mercury, PCB's and other toxic compounds 10 times higher than safety levels recommended by the Foods Standards Authority of Australia and New Zealand"

Southern Cross University

North Sea and public health

Oily fish are meant to be healthy ?

UK, National Health Service

"Pregnant women should not eat more than two oily fish per week from the North Sea because of pollutants such as dioxins and PCBs (polychlorinated biphenyls)"

Farmed salmon 40 ug/Kg PCBs (wet weight)

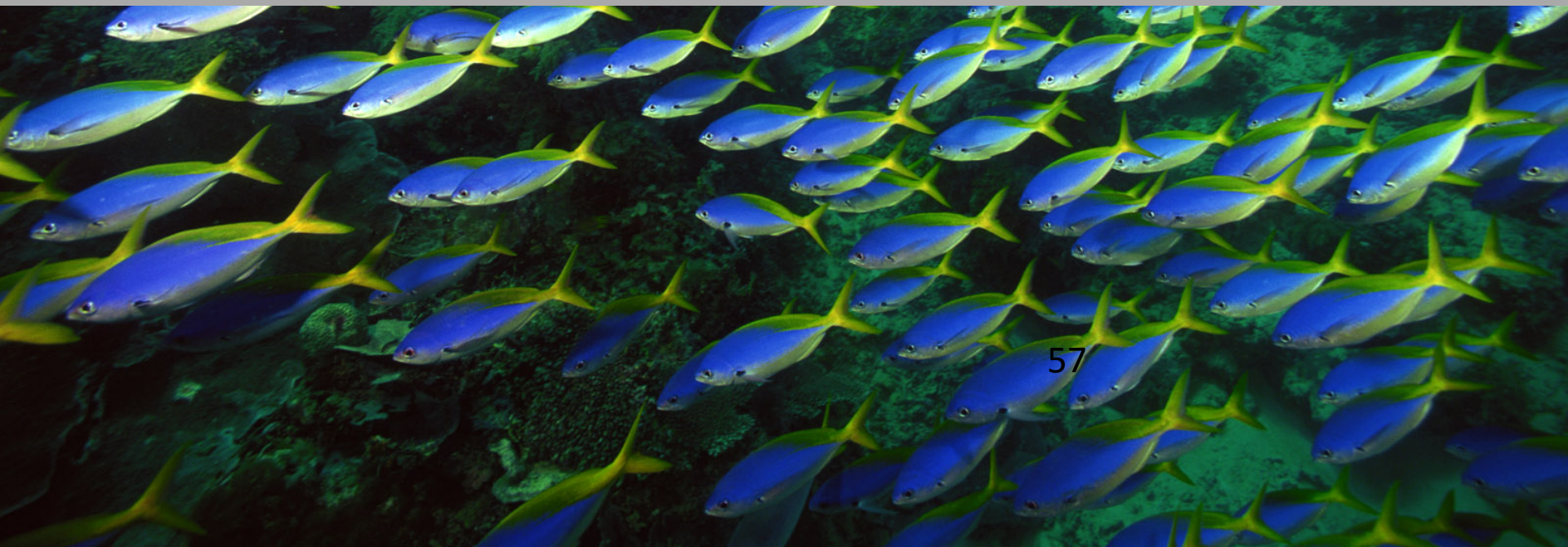
If the PCB level is higher than 48ppb, the EPA recommends not to eat the fish.


The reduced availability of krill during the summer feeding season is causing pregnant mothers to abort and calves to die.
National Geographic

95% of all life on Earth are microscopic plankton. They are responsible for 50% of all atmospheric CO2 fixation.

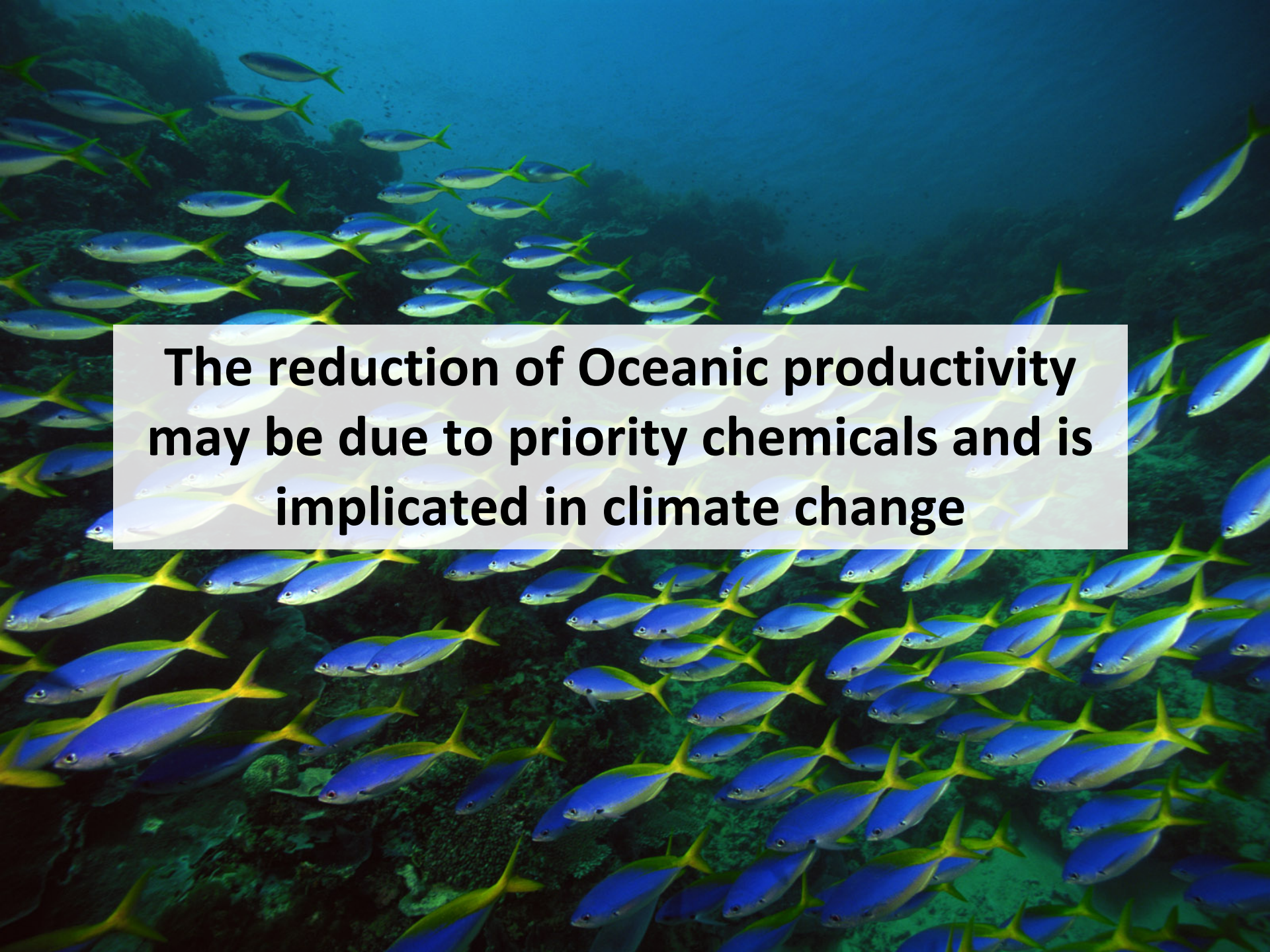
Primary productivity & biodiversity

- **Since 1950 the oceanic primary productivity of plankton may have reduced by UP TO 40%, (nature 2010), but even if it is only 5%, this is still a huge number**
- **Manufacture of priority substances started during the 1950s**



Primary productivity & biodiversity

- **NASA state that primary productivity is dropping by 1% per year since 1998, from satellite imagery**
- **Bios in Bermuda report a shift from coccolithophores (carbonate based) to diatoms (silicon based)**


The reduction of Oceanic productivity may be due to priority chemicals and is implicated in climate change

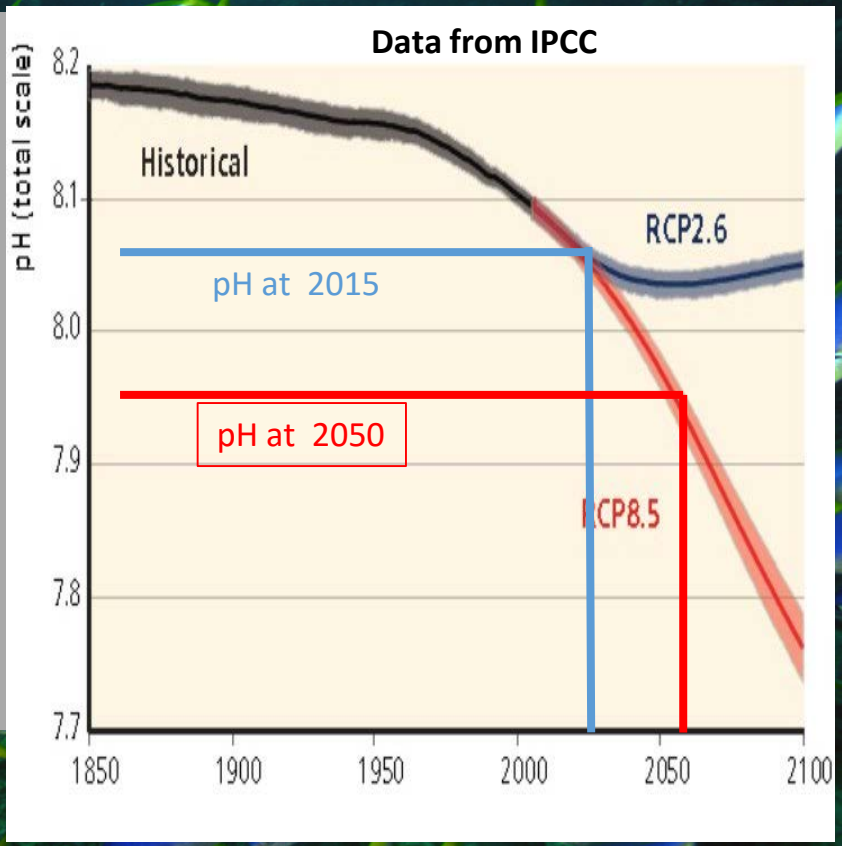
pH and ocean acidification

CO_2 dissolves into the water and drops the pH

The 40% reduction in productivity accelerates the acidification because CO_2 is not being used as a carbon source

At current rates in 35 years, oceanic pH will drop to pH7.95, at which point there may be a cascade destabilization of the marine ecosystem.

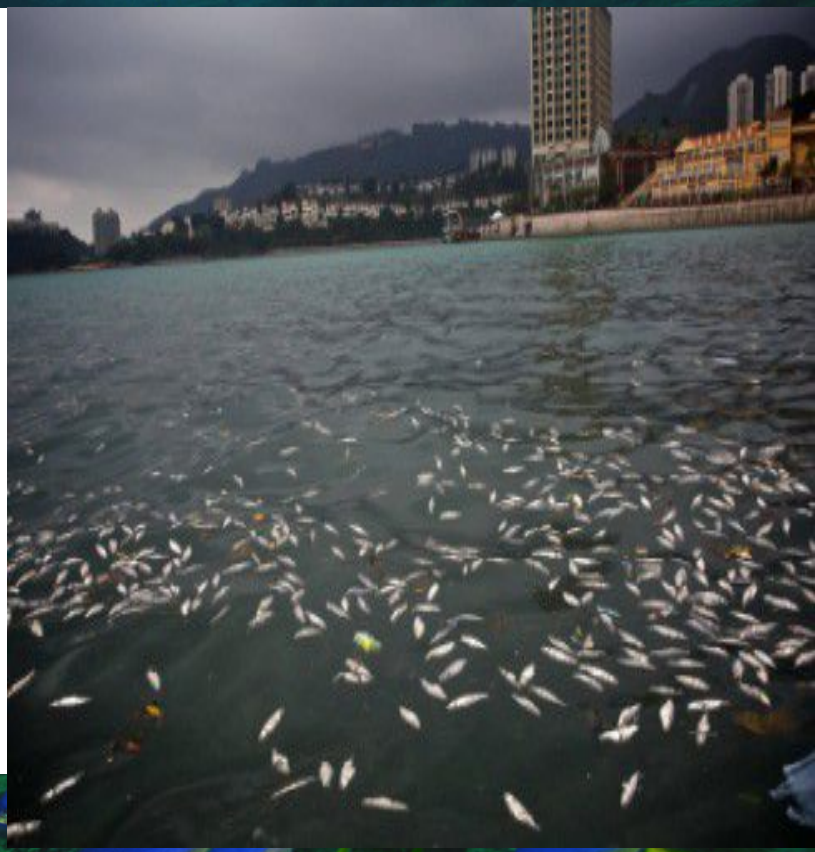
Many marine fish and invertebrates can not reproduce at a pH below 7.95



Potential consequences

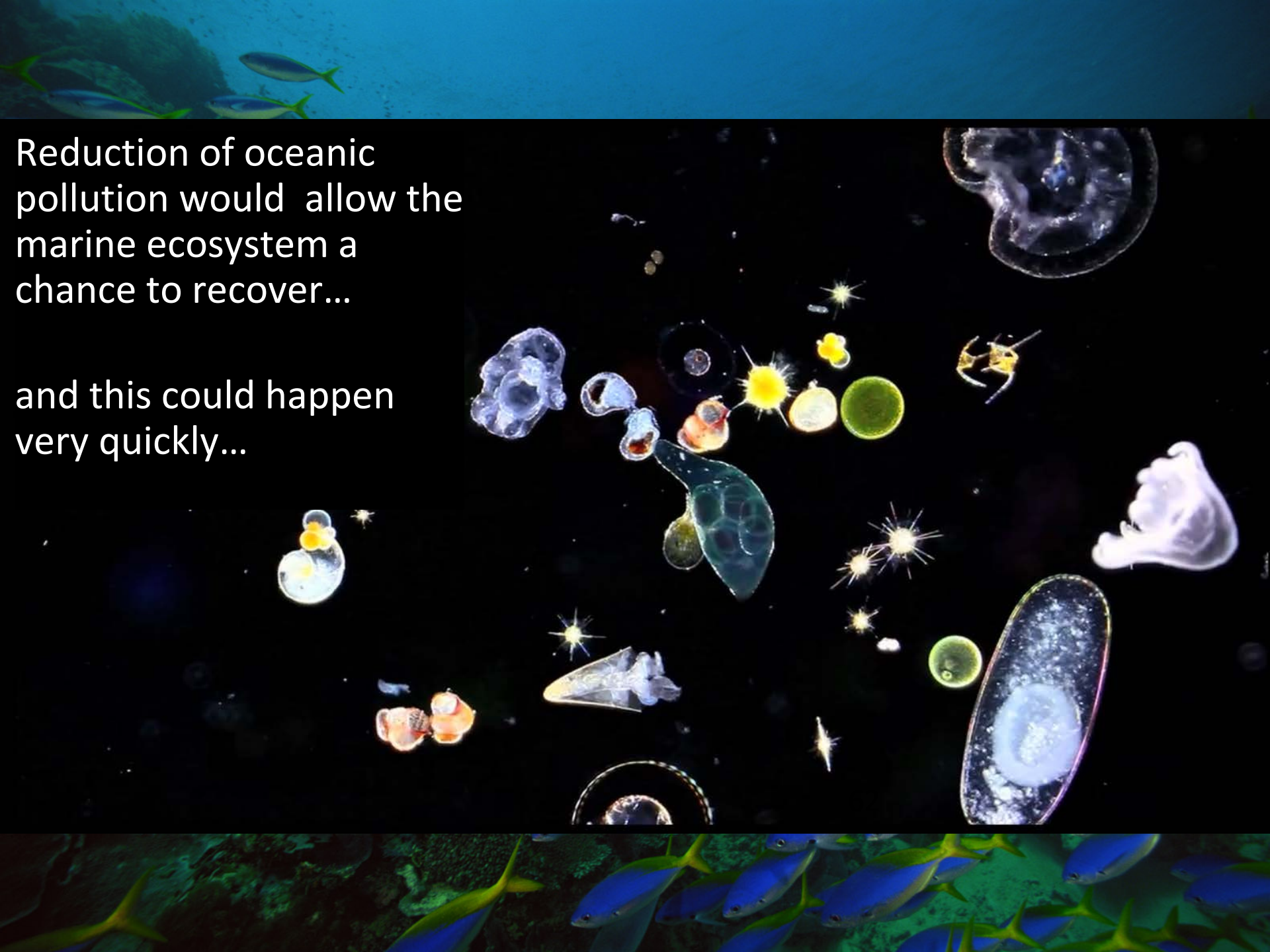
When the pH reaches 7.95 in 25 to 40 years, the consequences could be;

- No more marine teleost fish
- No fish then no dolphins, whales, seals, penguins, seabirds or polar bears
- Food supply for 1.5 billion people under threat
- Coccolithophores will be replaced by diatoms, fixation of atmospheric CO2 drops, climate change accelerates



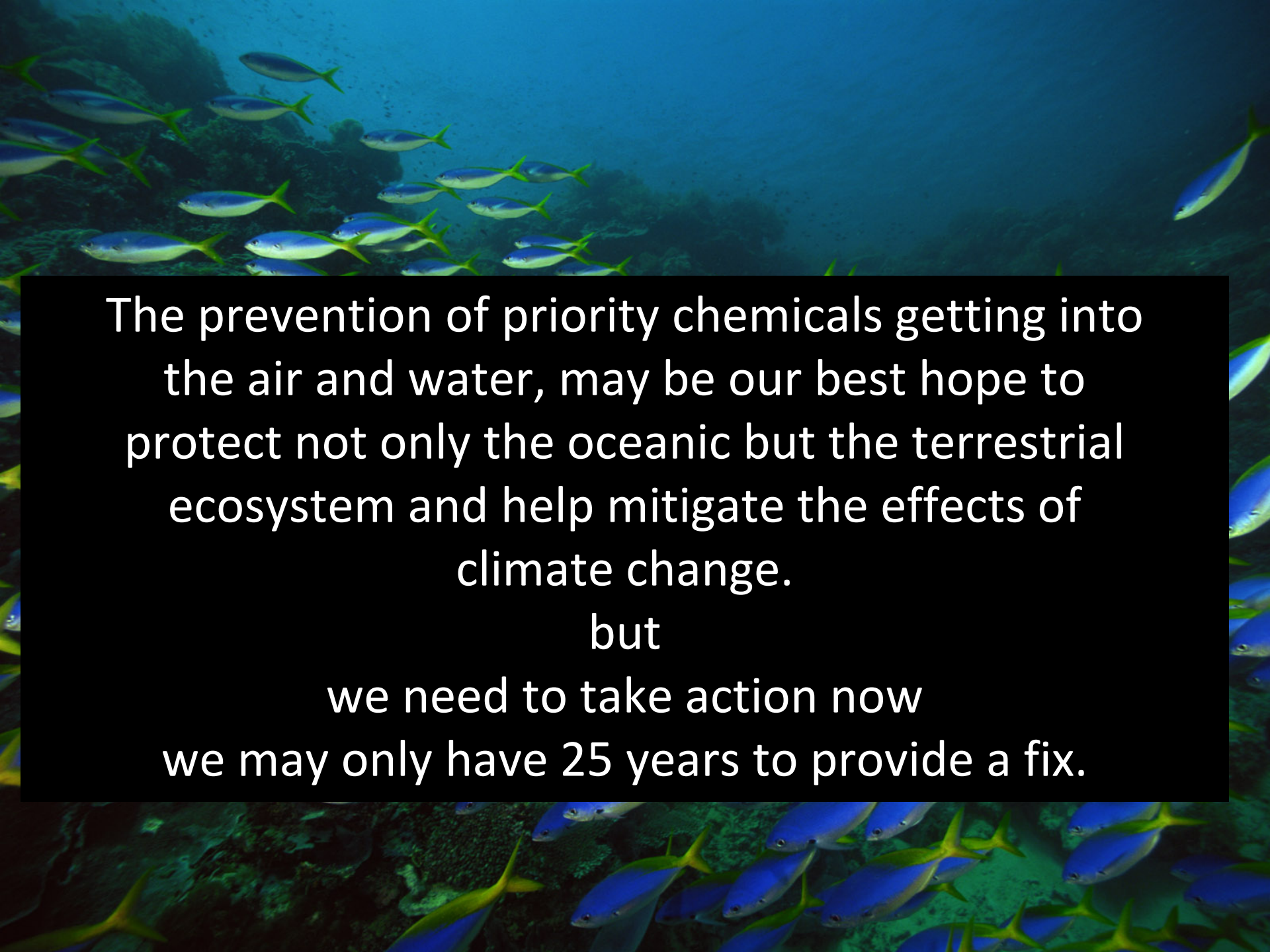
Reduction of oceanic pollution would allow the marine ecosystem a chance to recover…

and this could happen very quickly…




Marine Algae takes a few hours / days


Marine Bacteria take a few minutes



The prevention of priority chemicals getting into the air and water, may be our best hope to protect not only the oceanic but the terrestrial ecosystem and help mitigate the effects of climate change.

but

we need to take action now

we may only have 25 years to provide a fix.

Opportunities… green growth and development of a circular economy

Prevention of priority chemical pollution;

- Development of new domestic products, cosmetics, cleaning agents, fire retardants
- Pharmaceuticals, domestic treatment systems
- Technology to recycle waste, eg PCs, mobile phones
- Prevention of pollution, disposal stratigies & catchment area management
- Water treatment technology to remove the chemicals from drinking water and wastewater.

www.GoesFoundation.com

You can’t control water you don’t measure.

GOES, Global Oceanic Environmental Survey

- Collect information
- Raise awareness of the issues
- Provide possible solutions