Marine biodiversity

And its implications with regards to climate change.
A unifying hypothesis

about Dryden Aqua

Dryden Aqua are biologists specialising in marine and freshwater chemistry and the design of wastewater treatment systems.

We are possibly the only marine biological company specialising in wastewater treatment, so we have the tools required to relate water treatment to the wider aspects of environmental pollution, and the impact that certain types of pollution have on marine biodiversity and public health.

Marine phytoplankton and bacteria are responsible for over 80% of the CO_2 fixation and have an important role in cloud formation and the reflection of solar energy.

Issues relating to climate change should consider the health of the oceans and marine biodiversity, given that it has been the primary mechanism for controlling atmospheric conditions during the life of the planet.

Conditions have now changed and anthropogenic factors have impacted on the ocean ecosystems. This presentation attempts to bring current theories on climate change under one unifying theory to provide a possible explanation and perhaps a solution that explains climate change.

Pollution and refuse reaches all oceans and seas, some pollution is obvious, but it is the dissolved chemicals and sub-micron particles that are of more concern.

Could there be another reason for climate change ?

Climate change or warming is attributed to higher concentrations of CO_2 in the atmosphere derived from the combustion of fossil fuels.

Anthropogenic contribution to CO_2 is less than 5% of the total (from IPPC), and some estimate it at less than 0.5%. Deep ocean vents and volcanic activity release most of the CO_2, but it is not known how much is derived from this source, hence the disagreement regarding the anthropogenic contribution.

Dissolution of CO_2 into the oceans or the inability of marine phytoplankton to use the slightly elevated CO_2 has resulted in the Oceans becoming more acidic. This is simple chemistry that has been well documented and it seems to exactly match the increased contribution from man. 150 of the leading marine researchers report via the Monaco Declaration 2010 that the oceans are acidify 100 times faster than can be explained by natural variation.

CO_2 is required by phytoplankton, all photosynthetic and autotrophic organisms, It might have been expected that with the extra CO_2, oceanic productivity would have increased by a small percentage required to cancel out the extra contribution by man. However this has not happened, indeed it is quite the reverse has occurred.

Could there be another reason for climate change ?

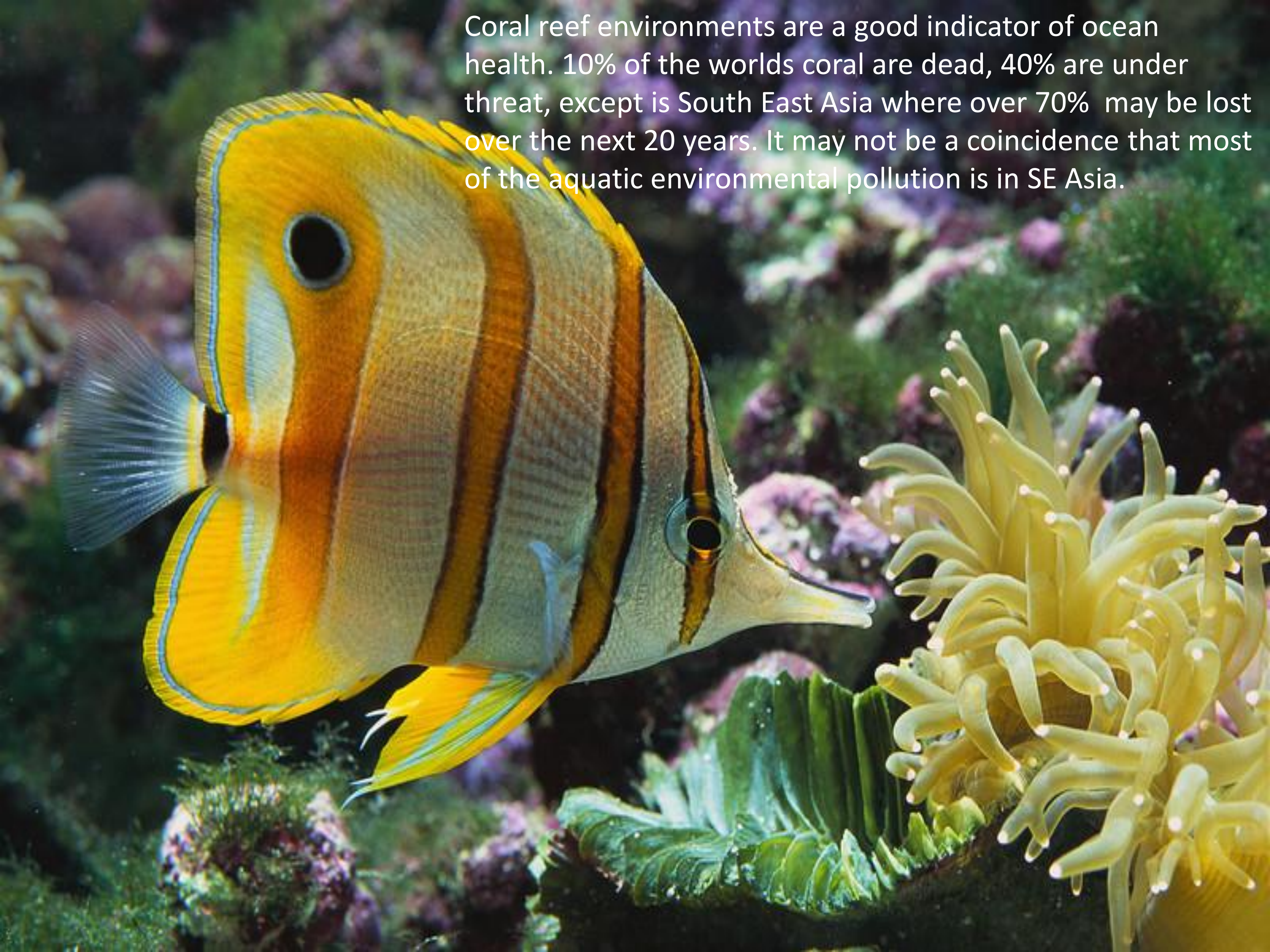
Phytoplankton play an active role in the formation of clouds which is explained latter in this presentation. A 1% increase in cloud cover could reverse all effects of global warming. Yet with all the extra CO_2 and nutrients being pumped into the oceans, this has not happened. Indeed there may have been a 40% decline in photosynthetic activity over the last 60 years in the North Atlantic and other Oceans that can not be explained by a change in oceanic currents.

A hypothesis is presented that may provide a possible explanation for the observations. Aquatic environmental pollution and inhibition of phytoplankton CO_2 fixation may be an important mechanism, and that the increase in atmospheric CO_2 and ocean acidification is the consequence of the underlying inhibition of photosynthesis.

Anthropogenic CO_2 is of course very important, but there has been no increase in ocean productivity to utilise the extra carbon, instead there has been a decline. There will be reasons for these changes; reduced trace nutrients, toxic bioactive chemicals, or maybe a change in light spectra due to atmospheric dust particles (4).

Elevated CO_2 and climate change may be an indicator of an under-lying issue relating to marine biodiversity and the stability of the ecosystem as a consequence of aquatic environmental pollution derived from wastewater discharges and atmospheric fall-out.

Coral reef environments are a good indicator of ocean health. 10% of the worlds coral are dead, 40% are under threat, except is South East Asia where over 70% may be lost over the next 20 years. It may not be a coincidence that most of the aquatic environmental pollution is in SE Asia.

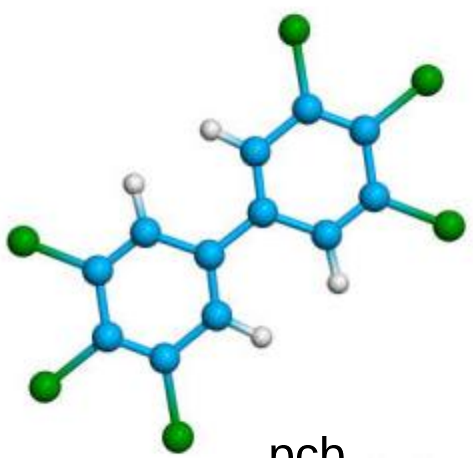


Chemical pollution

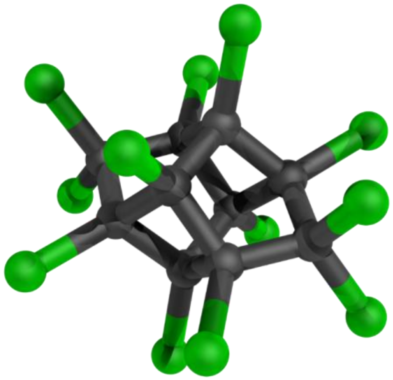
Sewage and industrial effluent contain a low concentration of organo-chlorine chemicals such as PCB`s (polychlorinated biphenyl's) and TBT (tributyltin), Flame retardants such as polybrominated diphenyl ethers (PBDEs) are of serious concern.

The chemicals are concentrated by organisms in the marine environment through a process known as chain amplification or bio-accumulation.

Over the last 60 years there has been a huge increase in the amount and type of chemicals manufactured by industry and used in the home. These chemicals all end up in sewage effluent or industrial wastewater, the most dangerous of which are the persistent bio-accumulated bio-active chemicals.



pcb



PBDE

Bio-active chemicals

The chemicals are normally associated with suspended solids which reduces the concentration in solution.

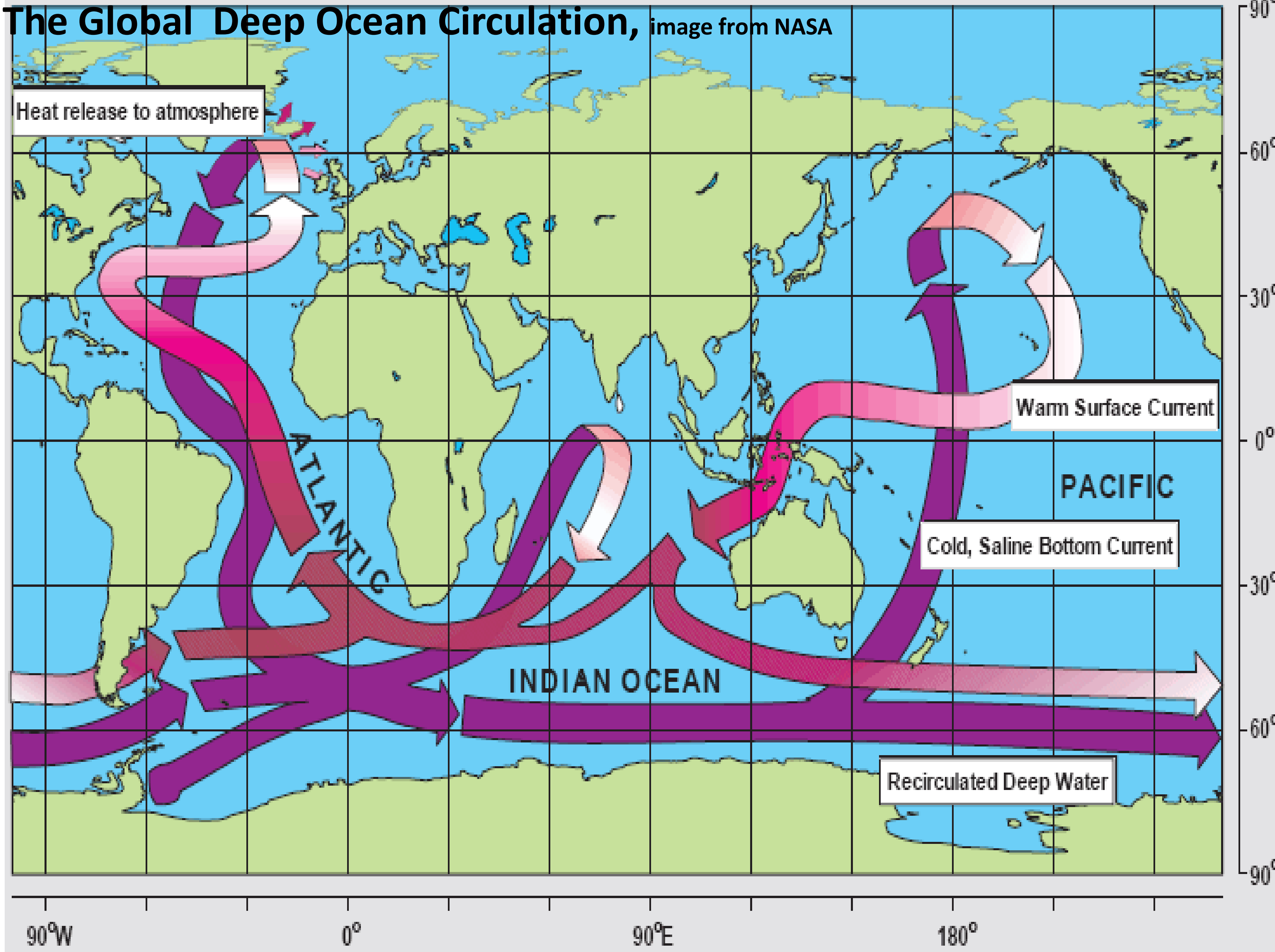
Suspended solids are not analysed by most environmental laboratories. Example. The UK Environment Agency report 0.025 ug/l PCB`s in North Sea, but Marbef report 8.8 ug/l in the North Sea and 1.2 ug/l in Antarctica when suspended solids are taken into consideration.

The problem is hidden because the environment agencies often only report the soluble fraction which will always be very low and usually in compliance to discharge regulations.

Very few effluent treatment systems are equipped with tertiary filtration to remove suspended solids down to concentration below 5mg/l, so the discharge of bioactive chemicals is progressing undetected.

Even although TBT and PCB manufacture is not permitted, they are still present in treated wastewater. Polybrominated diphenyl ethers (PBDEs) fire retardants are increasing and they all end up distributed in the worlds oceans.

The Global Deep Ocean Circulation, image from NASA



Pollution.. Cause and effect

Marine bacteria and phytoplankton (single celled plants) can concentrate bio-active chemicals and recycle them back into the human food chain.

By way of example, Minamata disease in Japan was caused by mercury (Japan 1956) which was turned into methyl mercury by bacteria, accumulated by algae and was then absorbed by shellfish which ended up back in the human food chain.

10,000 people affected

Nearly 2000 human mortalities as of 2002

People are still suffering form the disease

There are still high concentration of mercury in the pacific, and also the Mediterranean

Methyl mercuric chloride

Mercury & PCB`s

Mercury is bio-accumulated in tuna found in the Mediterranean & Pacific Ocean.

The concentration of bio-active chemicals (PCB`s) have increased in the North Sea to the point where it may not be safe to consume more than one or two oily fish per week, (UK Food Standards Agency) . Yet PCB`s are no-longer manufactured, and discharge to the environment is not permitted, so why are the concentrations increasing?

There can be no safe level for persistent bio-accumulated toxic chemical, because nature has not evolved a mechanism to cope with the chemicals. During the life of the planet it was predominantly marine phytoplankton that regulated atmospheric conditions. This mechanism appears to be failing and it is likely that anthropogenic influences are an important factor.

Bio-active chemicals are also implicated in causing many forms of cancer and neurological harm. We may be getting better at treating cancer, but the number of cases are increasing exponentially so now 1 in 3 of us will succumb from the disease

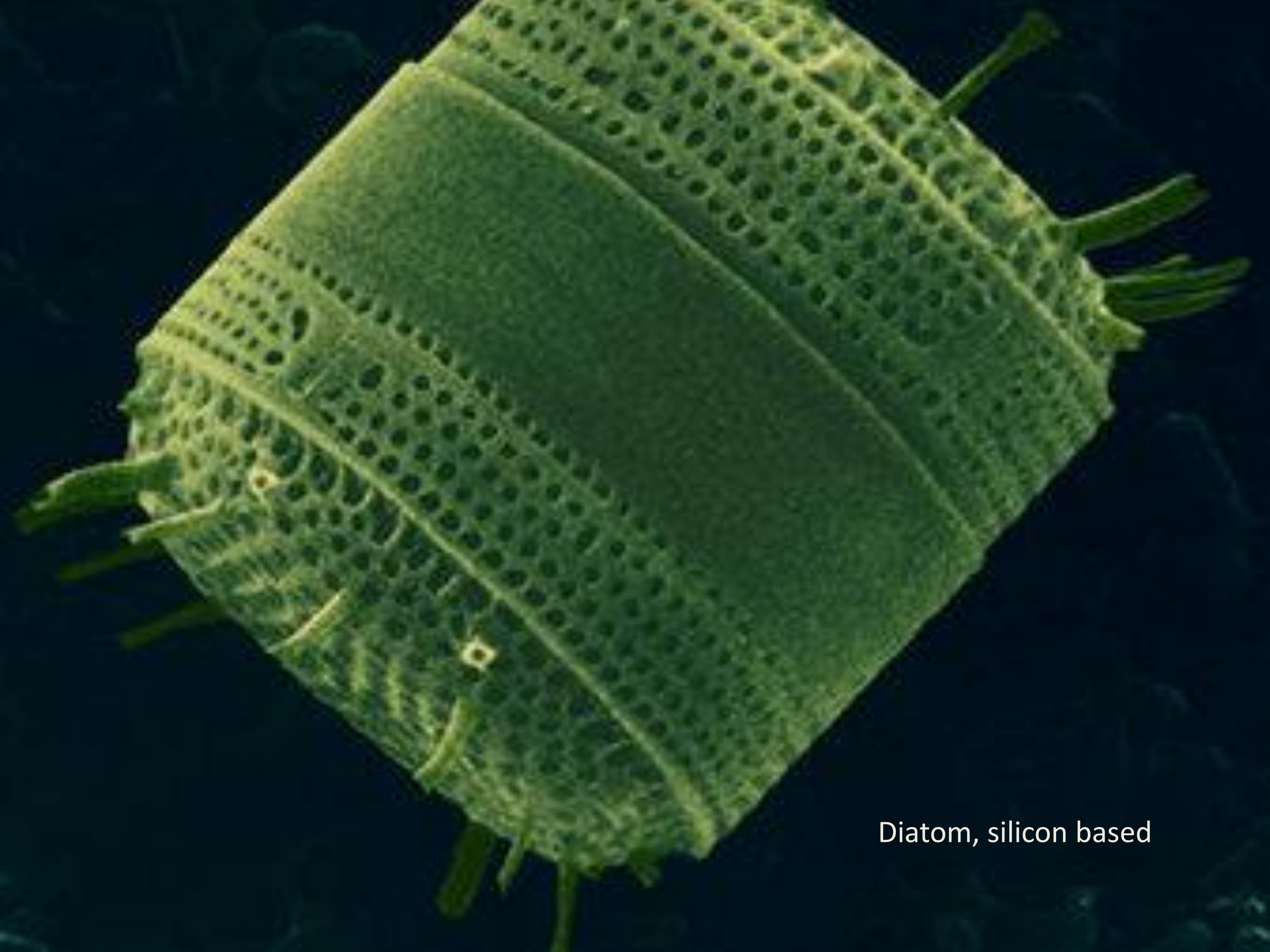
The ecosystems ability to fix CO_2 is being compromised

Marine phytoplankton such as coccolithophores & diatoms are responsible for over 80% of the world's oxygen production and along with autotrophic organisms for most of the carbon dioxide fixation, any change to marine biodiversity and phytoplankton productivity will have consequences.

Terrestrial ecosystems such as tropical rain forests and temperate northern forests are carbon neutral. When trees grow they absorbed CO_2, when they die they decompose and release exactly the same amount of carbon. However rain-forest create their own micro-environment which forms clouds, and the clouds reflect solar energy.

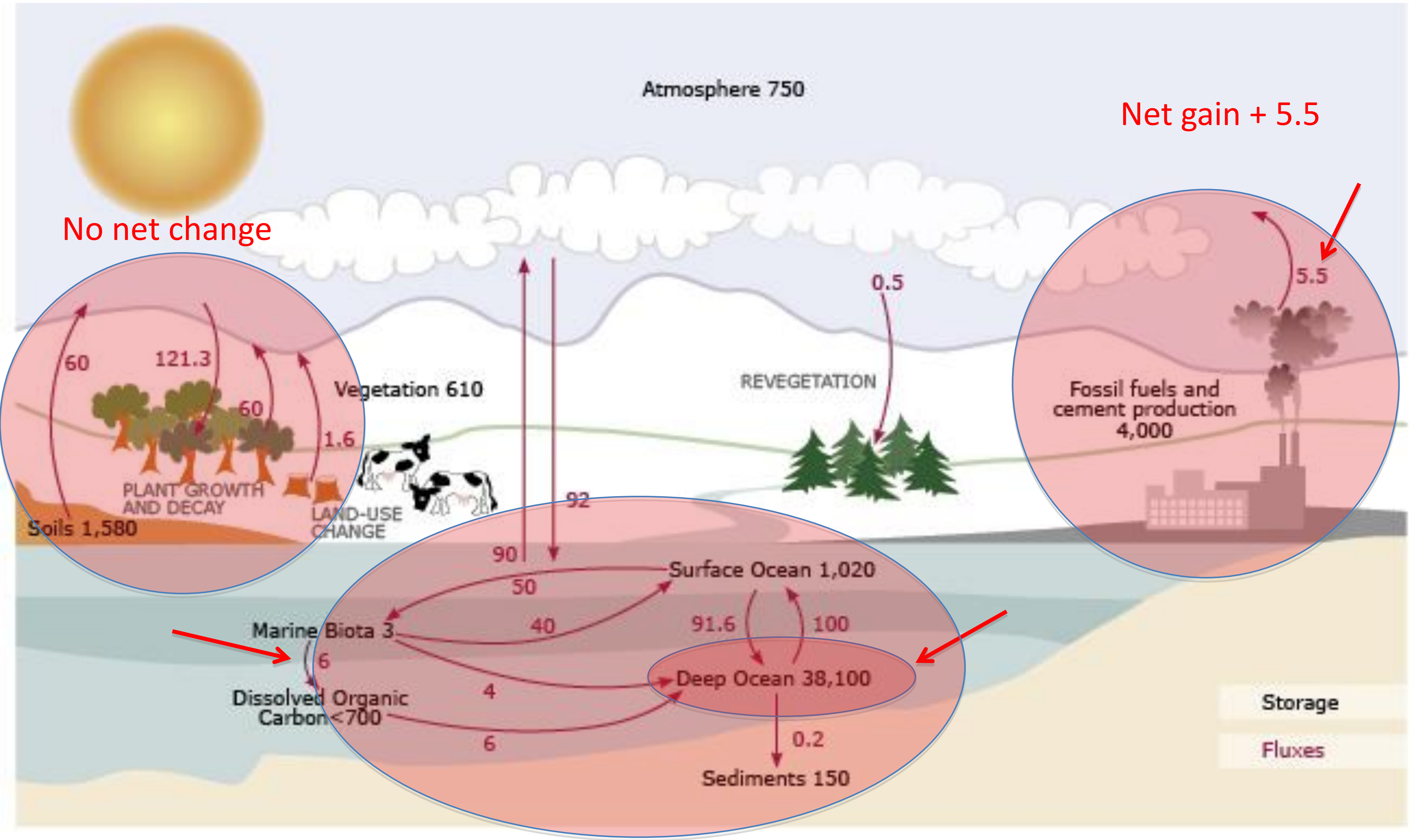
The only terrestrial system that can fix carbon are peat bogs and marshland which accounts for approx 10% of the total. When a marsh plant dies it does not decompose to release CO_2. The plant material is preserved or it is slowly digested over possibly 100`s of years to release methane.

The increase in temperature is thawing permafrost marshland to release trapped methane as well as solid methane nodules from the deep oceans. Methane release will accelerate climate change.



Diatom, silicon based

75% to 95% of CO2 fixation is by the Oceans



Net loss -2

Units: Gt and Gt/yr

1 Gt = 1,000,000,000 tons

Marine phytoplankton help to control the global climate

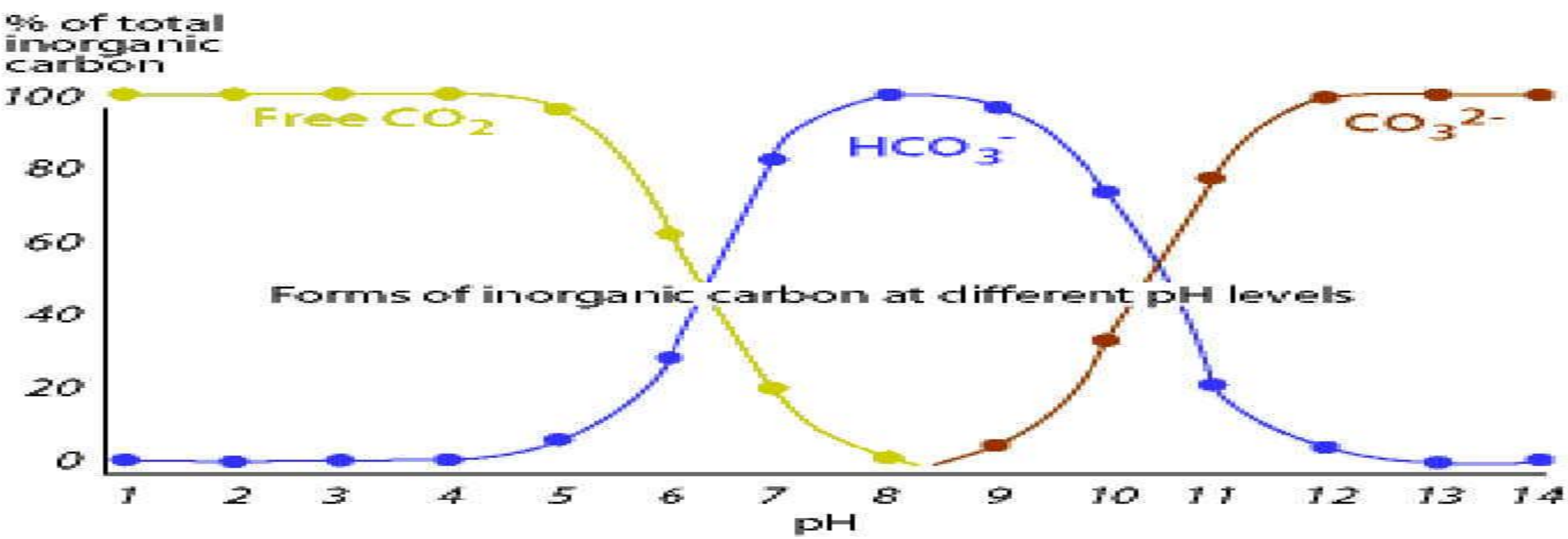
Coccolithophore carbonate based
Millions of tonnes of CO_2 are fixed as part of there calcite shell. If the water becomes acidic CO_2 concentrations increase a productivity increases. However if the water becomes too acidic below a pH of 7.9 , the calcite shell will start to dissolve.

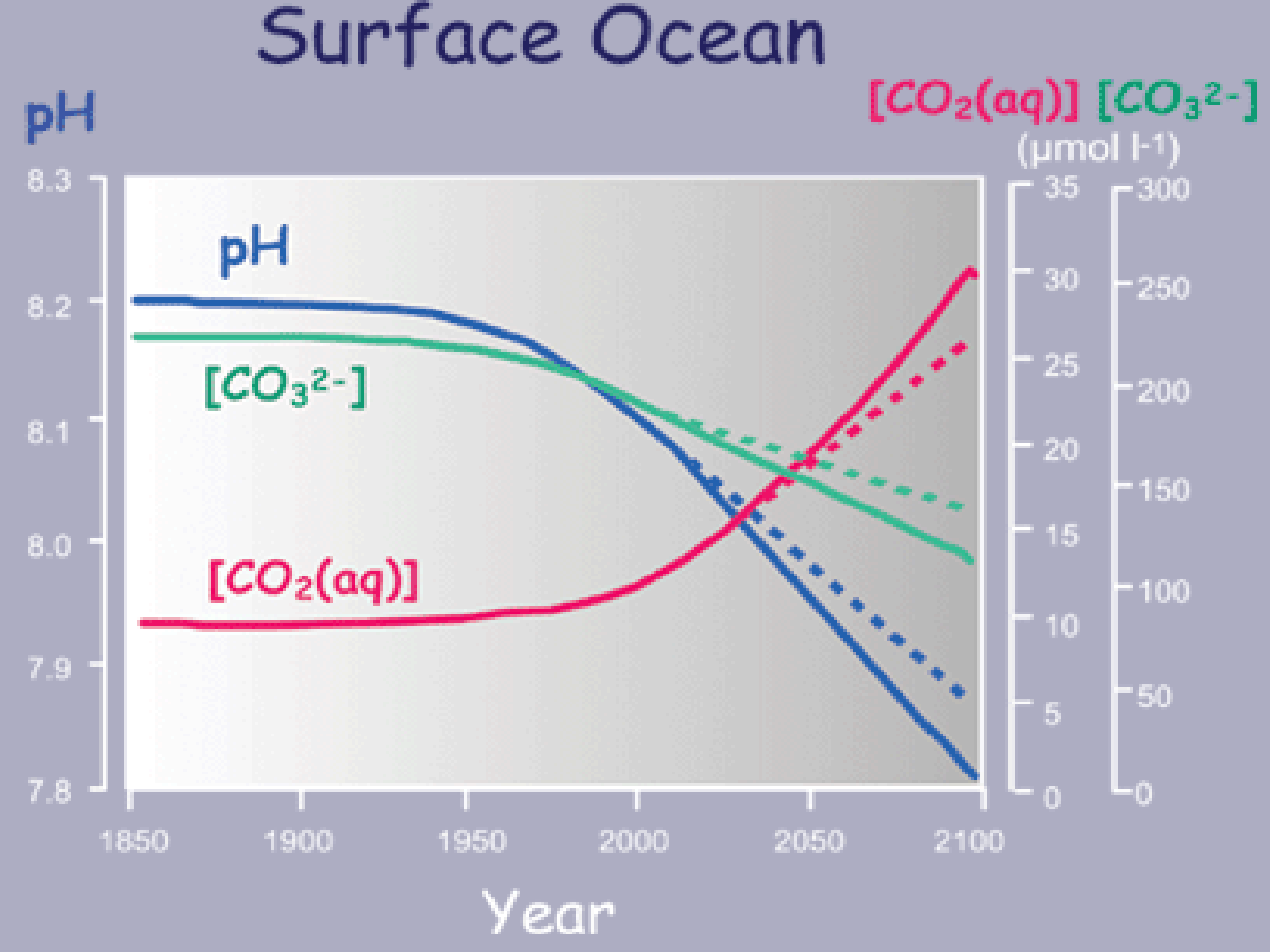
Acidification of the oceans

We have already seen a 0.1 to 0.2 pH drop in the world's oceans and huge shifts in marine biodiversity.

Most governments and research laboratories around the world relate acidification directly to increased dissolution of carbon dioxide into the sea because of the higher concentration in the atmosphere. The figures balance and it would seem to make perfect sense, but it may not be correct.

We consider that a reduction of carbon dioxide fixation by phytoplankton as a consequence of bio-active chemical toxicity has allowed the carbon dioxide levels to increase. The net results are the same but the mechanism is completely different.




Surface Ocean
pH
[CO_2(aq)] [CO_3^{2-}]
(μmol l-1)
8.3
8.2
8.1
8.0
7.9
7.8
pH
[CO_3^{2-}]
[CO_2(aq)]
35
30
25
20
15
10
5
0
300
250
200
150
100
50
0
1850
1900
1950
2000
2050
2100
Year

Fossil fuels, CO2 and aquatic pollution

There has been an increase in carbon dioxide concentration in the atmosphere attributed to the burning of fossil fuels, but we would have expected phytoplankton productivity and carbon dioxide fixation to increase and reach equilibrium with the carbon dioxide emissions, especially with all the extra nutrients being pumped into the oceans, but this has not happened.

In phytoplankton aquaculture farms we pump carbon dioxide into to water and add nutrients such as ferrous in order to grow algae. The Royal Society of London published a comprehensive overview of ocean acidification, and confirmed that calcification and photosynthesis both increase under elevated atmospheric pCO_2,

However over the last 60 years marine algae levels may have dropped by as much as 40%
.

Sewage effluent discharge has improved but it is still not in compliance to the Royal Commission standards of 1898. On the left is typical sewage effluent, on the right filtered sample of the same effluent.

Tertiary treatment of sewage effluent and industrial waste water is not difficult.

Phytoplankton and PCB toxicity

Dalhousie University Nova Scotia in a report published by Nature Journal measured a 40% reduction in marine algae in the North Atlantic and that the existing procedures used to measure phytoplankton are suspect as they tend to give an over-estimate.

A pH reduction from pH8.2 by 0.1 to 0.2 units in oceanic seawater supports the hypothesis and is absolutely catastrophic for the marine environment. Marine ecosystem and the ability of marine organisms to function are very closely related to the pH of the water.

DrydenAqua design some of the largest marine aquarium systems in the world and we know from experience that if the pH drops to 7.9 then marine ecosystems will start to fail.

The organic matter discharged by sewage works will have an impact on the environment but nature can usually adapt to natural wastes, it is the un-natural bio-active chemicals that are the problem. The chemicals will slow down or prevent phytoplankton growth, oxygen production and carbon dioxide fixation.

Sewage effluent and industrial wastewater should not contain bio-active chemicals, but this is not the reality. Water analysis is usually of filtered water samples, and since bio-active chemicals are bound up in solids they are not always measured.

The UK Environment Agency report PCB concentration of 0.025 ug/l in the North Sea but when solids are factored into the equation the actual level of PCB`s are 300 times higher

Phytoplankton and PCB toxicity

Harding et al 1978 showed that 1ug/l PCB inhibited photosynthesis.

Marbef measured PCB`s in marine suspended solids and related this to concentration and found that PCB`s in the North Sea were 8.8 µg/l and in Antarctica 1.2 µg/l.

Most bio-active chemicals are bound up in suspended solids, the polluted state of the North Sea might actually reduce PCB toxicity. Suspended solids pollution is lower in the Antarctic , bio-active chemicals are therefore more available for bioaccumulation by bacteria and algae. This is confirmed by measurements of high concentrations of bio-active chemicals in arctic whales, seals, birds and fish.

The lower concentration of bio-active chemicals in the clear ocean water are therefore more toxic than the higher concentration of the same chemicals found in coastal waters with a high suspended solids concentration.

The high concentration of nutrients around coastal water, coupled with suspended solids that have absorbed the bioactive chemicals has allowed phytoplankton blooms to develop. The blooms are un-natural, and out of balance boosted by the high concentration of nutrients and carbon dioxide to create DEAD ZONES. The coastal algal blooms could therefore be acting as a barrier preventing trace nutrients reaching the Oceans.

The dense concentration of phytoplankton shield the water of sunlight and use up all of the oxygen at night, the bloom collapses, bacterial decomposition uses up more oxygen and vast areas of coastal regions become dead zones, for all or part of the annual cycle.

The oceans are now becoming divided between oceanic deserts and unstable nutrient rich areas that are progressively developing into dead zones.

Dead zones and eutrophication

Eutrophication with nitrogen and in particular urea results in algal blooms.

Excessive blooms will cause Dead Zones

Certain species of algae especially Pseudo-nitzschia diatoms produce the neurotoxin domoic acid that cause amnesic shellfish poisoning in humans

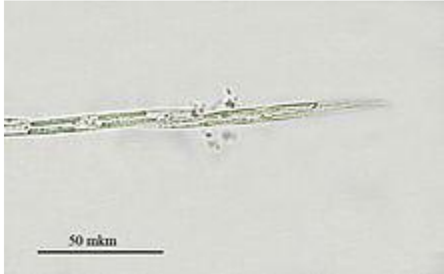
Domoic acid also causes brain damage to seals, fish eating birds and whales. Domoic acid is not a man-made pollutant, but it is manufactured by marine organisms, just like mercury is converted to methyl-mercury.

The beaching and death of whales has been linked to high concentrations of the neurotoxin.

It is believed that once exposed, brain tissue will suffer from scarring, this has been documented in seals. The human health affects have not been quantified.

The above is happening now, and is another example that demonstrates the need to protect the environment to help prevent potentially serious human health implications. The above also demonstrates the complex mechanisms and changes that can occur, even when it involves non toxic chemicals, toxic metabolic products can be formed.

Algae bloom south of England



Pseudo-nitzschia diatoms

Clouds and reflected energy

Tropical rain forests are carbon neutral, they do not fix CO_2, however transpiration of water through the trees generates clouds that reflect solar energy.

Marine phytoplankton produce large quantities of dimethyl sulphide which is oxidised in the atmosphere or reacts with cosmic rays to form aerosols of sulphur dioxide. The aerosol acts as nuclei for water condensation and cloud formation.

The clouds reflect light and this may be one of the most important mechanisms regulating the planets temperature.

Contrails from jet aircraft create artificial clouds, after 9/11 there was no air travel in the USA, average ground temperature increased by 1 deg C during the 3 day period.

If ocean temperatures increase, thermal stratification develops which prevents mixing of the deeper nutrient rich water with the surface water. Thermal stratification accelerates the decline of phytoplankton productivity, reduces cloud formation and allows temperatures to increase further.

Clouds and reflected Energy and global cooling

Pacific Decadal Oscillation (PDO) relates ocean temperatures to cloud formation would seem to be a close fit to climate change.

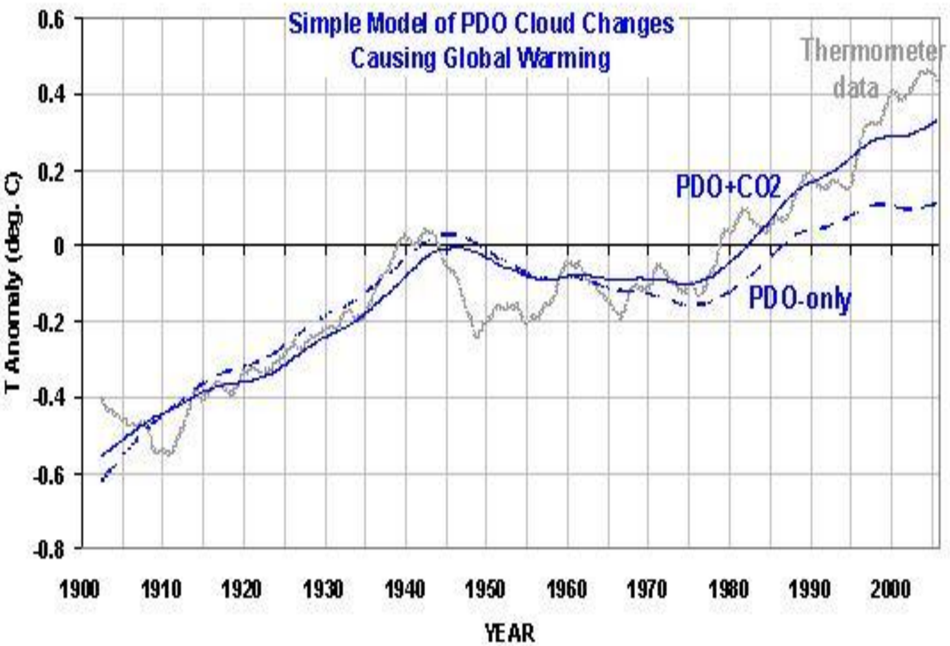
Reduced phytoplankton productivity results in less sulphur dioxide released by phytoplankton and fewer clouds.

Lower cloud cover allows more radiant sun energy to reach the sea and temperatures rise.

Any aquatic pollution that prevents photosynthesis therefore has the potential to cause an increase in temperature.

A 1% increase in cloud cover would reverse the changes of global warming.

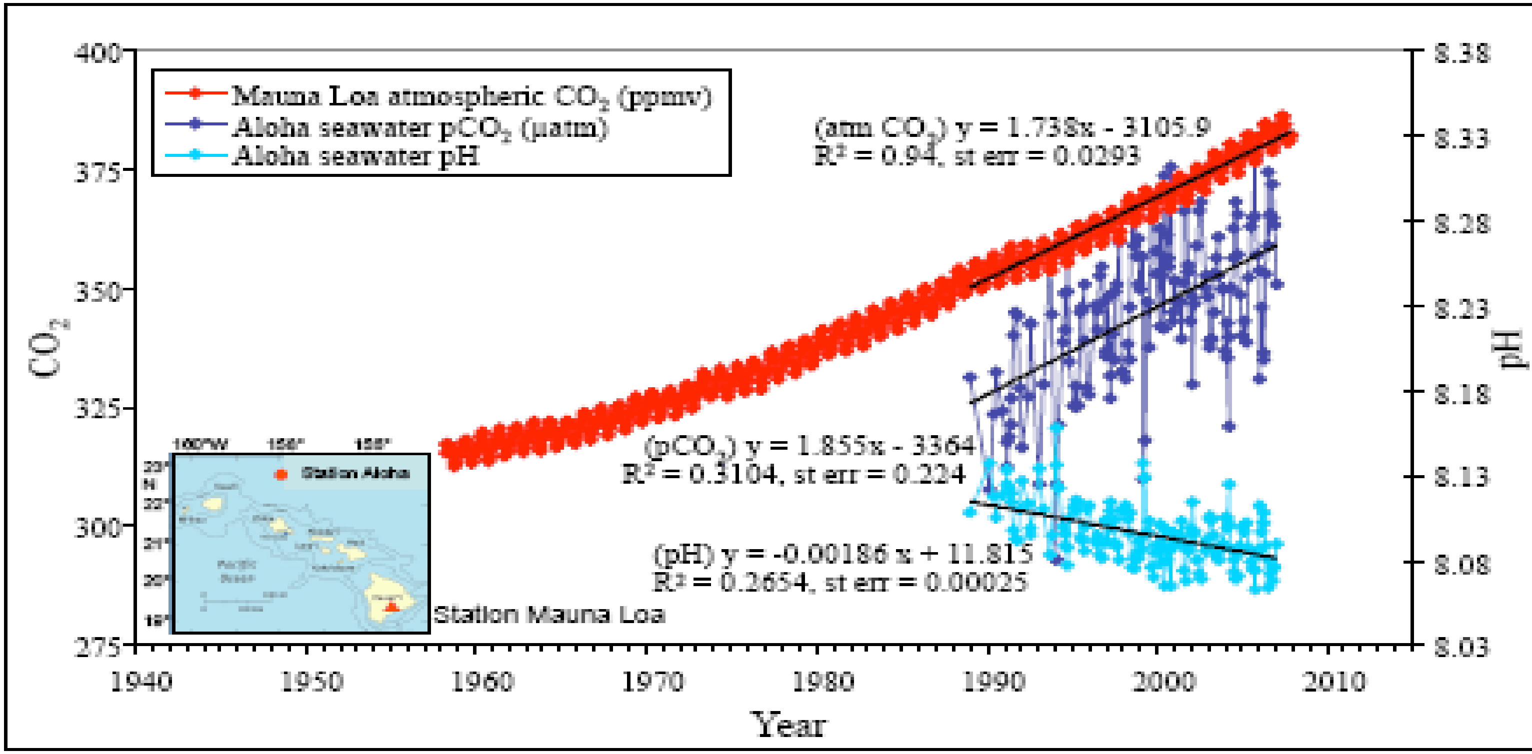
CO2 levels in relation to climate change would seem to be of less importance, but it is an indicator that something has changed.



A simple energy balance model driven by cloud changes associated with the PDO can explain most of the major features of global-average temperature fluctuations during the 20th Century. The best model fits had assumed ocean mixing depths around 800 meters, and feedback parameters of around 3 Watts per square meter per degree C. *Roy Spencer et al 2008, Senior Scientist for Climate Studies at NASA's Marshall Space Flight Centre.*

Note. A minor drop in oceanic pH will increase CO2 in solution and will stimulate phytoplankton productivity. This could explain the drop in temperature, 1950-75. After 1975, toxicological or trace element depletion becomes dominant and restricts phytoplankton productivity, allowing a temperature to increase., Prior to the Marinoan glaciation (snowball earth) there was an increase in CO2 but no anthropogenic pollution. CO2 may actually cause global cooling.

CO_2 Time Series in the North Pacific Ocean



Data from NRDC national resource defence council. The pH of the ocean is dropping in direct response to the partial pressure of CO2 in the atmosphere. The pH has now reached as low as pH8.08 in many locations.

The marine ecosystem is not responding, this is either due to a depletion of trace elements. Nitrogen, silica and phosphorous may also be limiting in some cases, or we have a toxin that is impacting on productivity. In any event when the pH drops below pH 8.00 and approaches pH 7.90 there may be a complete cascade destabilization of the marine ecosystem that could have more serious consequences than climate change.

The iron factor

Iron is a trace nutrient required for the growth of phytoplankton, a deficiency of iron will restrict phytoplankton growth.

Fertilisation trials have confirmed as little as 1 kg of iron as sub-micron particles can stimulate the growth of 100 tonnes of phytoplankton.

Iron can enter the marine ecosystem as wind-blown dust and as a component of waste water. However there would seem to have been a substantial reduction of iron in the oceans.

Organic suspended solids will be flocculated by iron, so minor increase in organic matter will strip iron out of the water, and the particles will fall to the abyss. Coastal phytoplankto blooms will remove iron, the carbon will be recycled but the iron may be accumulated in the sediment. Micro-plastics may also be implicated in this mechanism and acts as a carrier for bio-active chemicals.

Iron may also coagulate and then flocculate bio-toxins, this process is used in waste water treatment. Iron in combination with sunlight will increase hydroxyl radical concentration, redox potential increases and toxins are oxidised. The conditions are also favoured by phytoplankton that prefer an oxidative environment with high redox potential and low particle zeta potential.

So while iron is a micro-nutrient it may also be preventing toxicity from other chemicals, but it is also lost from the system via organic pollution and flocculation reactions.

Bio-active chemicals and the worlds Oceans

The sea is the main driving force controlling the atmosphere and is responsible for most of our oxygen production and carbon dioxide fixation. Methane is also fixed in the abyss under conditions of high pressure and low temperature.

The oceans are responsible for CO_2 fixation and O_2 production but the biomass of plants in the sea is low per unit area, especially when the water is very clean and clear.

Carbon fixation occurs off the continental shelf because when the phytoplankton die, they keep going down to the abyss, but in this clear water bio-active chemicals will have a greater toxicological impact on bacteria and phytoplankton. The marine ecosystem is therefore very delicately balanced.

The most toxic chemicals are usually associated with suspended solids, and they may not be detected in chemical analysis of waste water due to a deficiency with the analytical techniques.

AFM 20cubm/hr system on a sewage effluent treatment to test tertiary treatment of waste water for solids and bio-active chemical control.

Before & after AFM filtration, solids reduced by 90% and bioactive chemicals by the same percentage.

All countries must protect the aquatic environment

It is remarkable that most sewage effluent treatment systems do not have tertiary treatment to remove suspended solids containing bio-active chemicals.

Even if bio-active chemicals are not a major contributor to Global Warming, they are implicated in causing disease and serious damage to the marine ecosystem.

Aquatic environmental pollution of rivers, lakes and the marine environment has far reaching consequences that we do not fully understand, but by the time it has been quantified and analysed it may be too late to take remedial action.

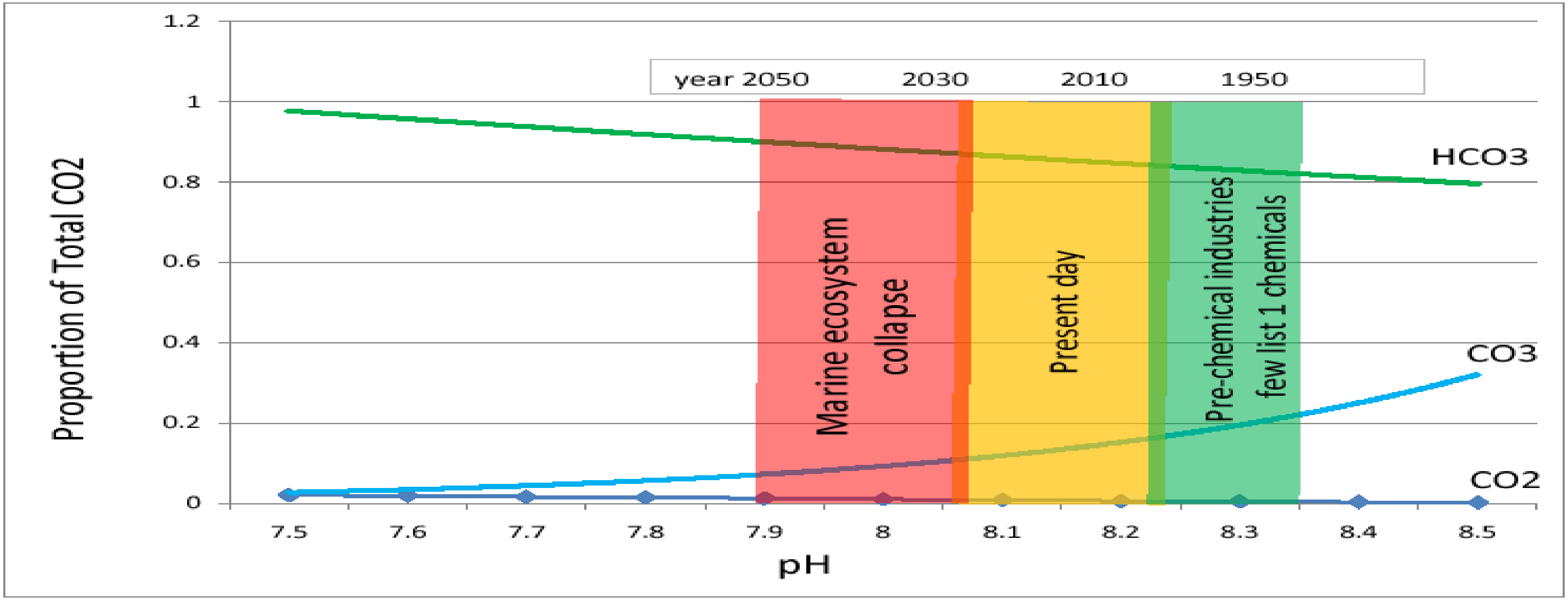
The technology for the tertiary treatment of sewage effluent and removal of bio-active chemicals has been developed and is available from many companies and can be retrofitted to most treatment systems.

The objective would be to reduce suspended solids to less than 5 mg/l, and eventually to achieve a standard less than 1 mg/l.

25 years left to solve the problem !

The Ocean surface pH values against year shows that acidification started in the 1950/60`s, with the chemical revolution…not the industrial revolution. The data from the Ocean Acidification Organisation supports the Dryden Aqua hypothesis that Global Warming is indirectly related to aquatic environmental pollution and not just CO2 emissions.

It is always dangerous to extrapolate data, but if this is applied, oceanic pH may fall to pH 7.9 – pH8.0 over the next 25 years and this will cause cascade destabilisation of the Marine Ecosystem. The terrestrial ecosystem is linked to the marine ecosystem, so potentially we have a situation that could be more serious than climate change.



final thoughts

We know that the concentrations of PCBs in all of the world's oceans are sufficient to reduce phytoplankton productivity and impact on aquatic mammals and birds and probably coral reefs. There will also be other bio-active chemicals and interactions with other waste such as plastic micro-particles. Measurements by Universities and Government laboratories has confirmed phytoplankton levels have dropped by 40%, but even if they are wrong and it is just 5%, this is still of huge number.

We also know that the pH of the oceans suddenly started drop in the 1950`s with the chemical revolution as opposed to the industrial revolution. Oceanic pH should be around 8.2, it is now under 8.1 if it drops by a further 0.1 to 0.2 units, we will have a cascade failure of the marine ecosystem which could be more serious than climate change.

Our hypothesis is that marine bio-active chemical pollution, or a combination of mechanisms involving iron, organic matter and sunlight, has impacted on phytoplankton productivity. Lower productivity has reduced CO2 fixation and cloud cover, and it is these factors have allowed CO2 and temperature to rise and pH of the oceans to become more acidic.

A great deal of work is required to quantify and verify all the statements in this presentation, but this should not detract from the content given the potential importance if confirmed. Even if the hypothesis is only partially correct, the control of marine environmental pollution is just as important as controlling greenhouse gas emissions because we all depend upon the marine ecosystem for our survival.

On a more positive note, if we are correct, then our hypothesis provides us with an elegant solution to help reverse the effects of climate change and stabilize the ecosystem by the prevention of marine aquatic environmental pollution achieved through filtration of wastewater discharges.


Dryden Aqua Ltd
Butlerfield, Bonnyrigg
Edinburgh eh19 3jq
Scotland
www.drydenaqua.com

References and useful links

1. James C. Or et al Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organism Vol 437|29 September 2005 doi:10.1038/nature0409
2. Boyce, D., Lewis, M. & Worm, B. (2010) "Global phytoplankton decline over the past century" Nature, 466: 591–596.
3. Ocean greenery under warming stress" Nature News, 28 July 2010. doi:10.1038/news.2010.379
4. Gayan Rubasinghege et al, Reactions on Atmospheric Dust Particles: Surface Photochemistry and Size-Dependent Nanoscale Redox Chemistry. J. Phys. Chem. Lett., 2010, 1 (11), pp 1729–1737 DOI: 10.1021/jz100371d
5. http://www.sahfos.ac.uk/
6. Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks. Mark Anthony Browne et al; Environ Sci Technol 2011, 45, 9175-9179
7. Recent climate change in the Arctic and its impact on contaminant pathways and interpretation of temporal trend data. Science of The Total Environment Volume 342, Issues 1-3, 15 April 2005, Pages 5-86
8. Clamer Report http://www.clamer.eu/outreach/booklet
9. TV program, The women how swims with Orca. http://www.bbc.co.uk/iplayer/episode/b0147dw3/sign/Natural_World_20112012_The_Woman_Who_Swims_with_Killer_Whales/