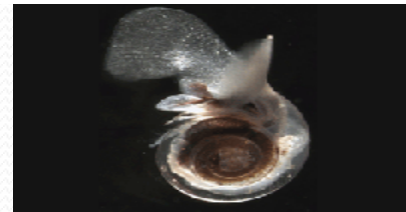
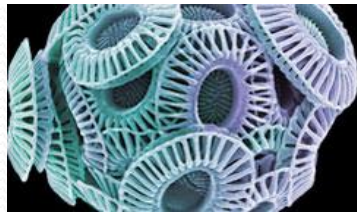
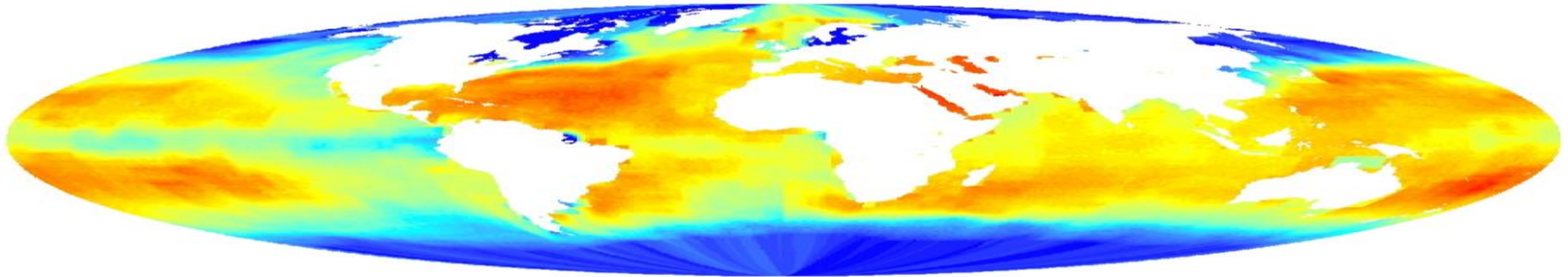


OCEAN ACIDIFICATION



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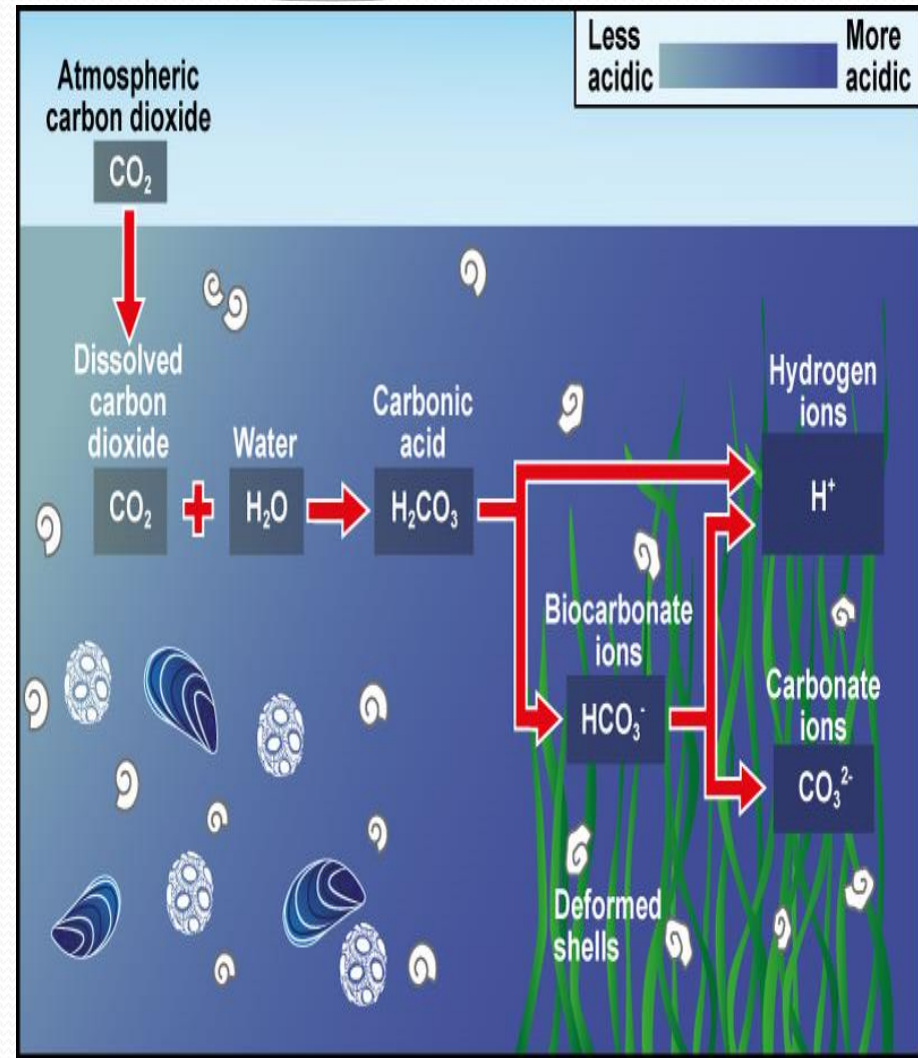
OUTLINE OF TALK

- What is ocean acidification?
- What we know about ocean acidification?
- What we need to know about ocean acidification?
- What we can do to mitigate ocean acidification?
- Conclusions
- Suggestions
- Recommendations



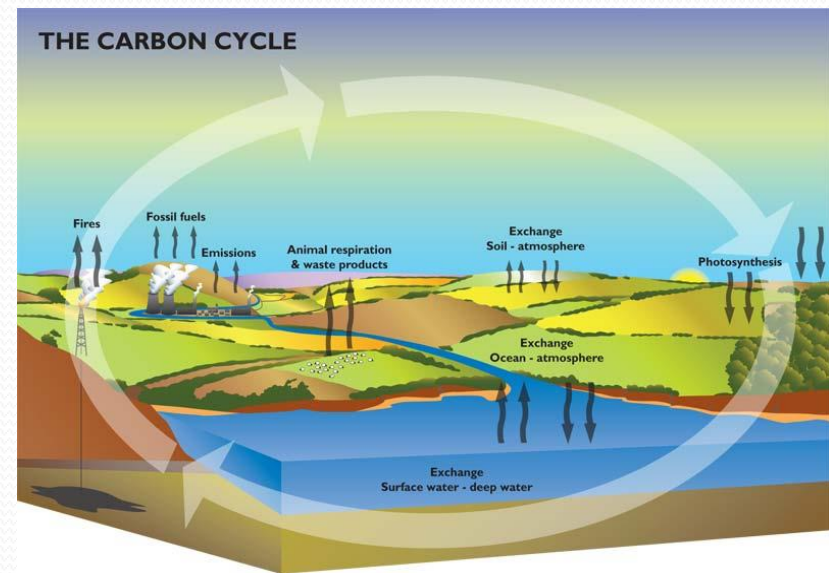
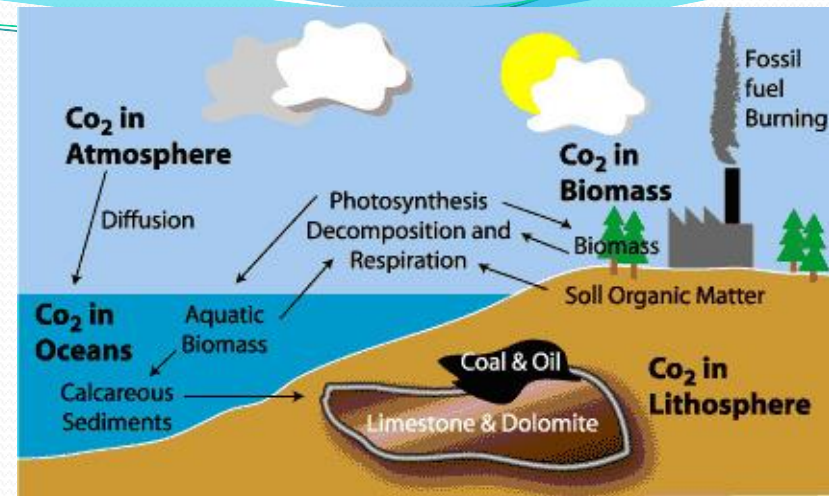
WHAT IS OCEAN ACIDIFICATION?

Ocean acidification is the ongoing decrease in the pH of the oceans, caused by their uptake of anthropogenic carbon dioxide from the atmosphere



What we know about ocean acidification?

- The carbon cycle describes the fluxes of carbon dioxide (CO_2) between the oceans, terrestrial biosphere, lithosphere, and the atmosphere.
- Human activities such as land-use changes, the combustion of fossil fuels, and the production of cement have led to a new flux of CO_2 into the atmosphere.
- Some of this has remained there; some has been taken up by terrestrial plants, and some has been absorbed by the oceans.



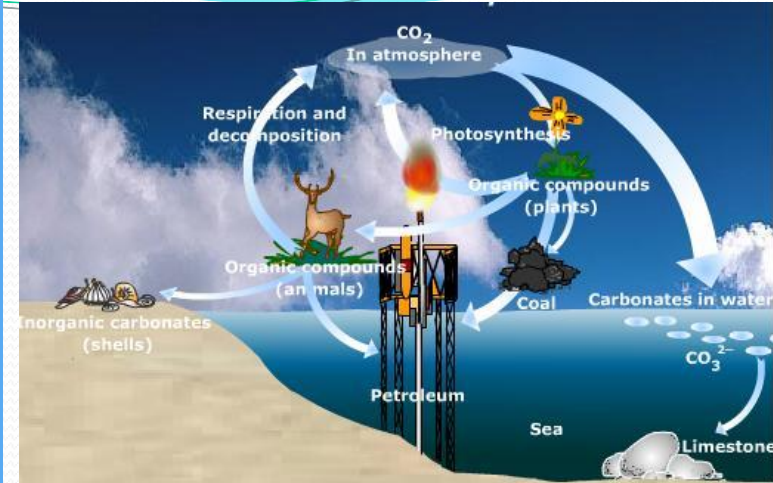
What we know about ocean acidification?

Time	pH	pH change	Source
Pre-industrial (1700s)	8.179	0.000	Key et al (2004)
Recent past (1990s)	8.104	-0.075	Key et al (2004)
2050 (2×CO ₂ = 560 ppm)	7.949	-0.230	model
2100 (IS92a)	7.824	-0.355	model

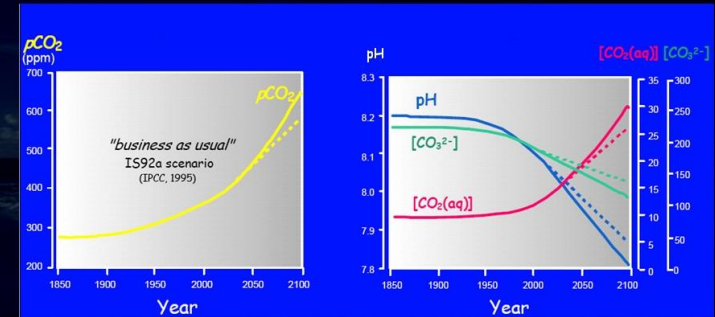


What we know about ocean acidification?

- The carbon cycle comes in two forms: the **organic carbon cycle** and the **inorganic carbon cycle**.
- The **inorganic carbon cycle** is responsible for ocean acidification for it includes the many forms of **dissolved CO_2** present in the Earth's oceans.
- When **CO_2 dissolves**, it reacts with water to form a balance of **ionic** and **non-ionic** chemical species: **dissolved free carbon dioxide ($\text{CO}_2(\text{aq})$)**, **carbonic acid (H_2CO_3)**, **bicarbonate (HCO_3^-)** and **carbonate (CO_3^{2-})**.
- Dissolving **CO_2 in seawater** increases the **hydrogen ion (H^+) concentration** in the ocean, and thus decreases ocean pH.



Rising atmospheric CO_2 is changing the chemistry of the ocean



After Wolf-Gladrow et al., 1999



What we know about ocean acidification?

- Changes in ocean chemistry can have **extensive direct and indirect effects on organisms** and the **habitats** in which they live.
- One of the most important repercussions of increasing ocean acidity relates to the **production of shells and plates out of calcium carbonate** (CaCO_3).
- This process is called **calcification** and is important to the biology and survival of a wide range of marine organisms.



WHAT IS CALCIFICATION?

Calcification involves the precipitation of dissolved ions into solid CaCO_3 structures, such as **coccoliths**. After they are formed, such structures are vulnerable to dissolution unless the surrounding seawater contains saturating concentrations of carbonate ions.

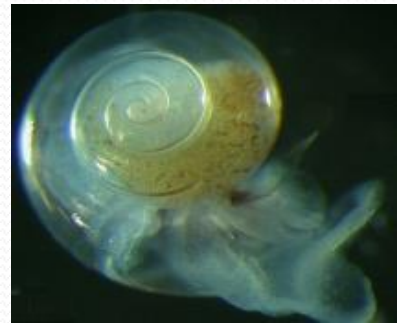
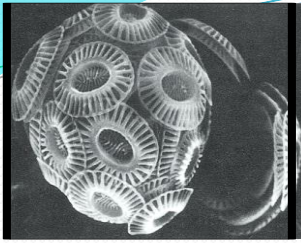


What we know about ocean acidification?

- Calcium carbonate occurs in 2 common polymorphs: **aragonite** and **calcite**.
- **Aragonite** is much more soluble than **calcite**, with the result that the aragonite saturation horizon is always nearer to the surface than the calcite saturation horizon.
- This also means that those organisms that produce **aragonite** may possibly be **more vulnerable** to changes in ocean acidity than those which produce **calcite**.



What we know about ocean acidification?



- Reduced calcification rates
 - Significant shift in key nutrient and trace element speciation
 - Shift in phytoplankton diversity
 - Reduced growth, production and life span of adults, juveniles & larvae
 - Reduced tolerance to other environmental fluctuations
 - Changes to fitness and survival
 - Changes to species biogeography
 - Changes to key biogeochemical cycles
 - Changes to food webs
 - Changes to ecosystem & their services
- Uncertainties great – research required

What we need to know?

Impact on phytoplankton

Acidification decreased ammonia oxidation rates and nitrification rates, affecting oceanic nitrous oxide production, reducing supplies of oxidized nitrogen in the upper layers of the ocean, and fundamentally altering nitrogen cycling in the sea (Beman *et al.*, 2011).

Acidification cause the anoxic condition in the sea.

Acidification of media containing various Fe compounds decreases the Fe uptake rate of diatoms and coccolithophores.

The ongoing acidification of seawater is likely to increase the Fe stress of phytoplankton populations (Shi *et al.*, 2012).



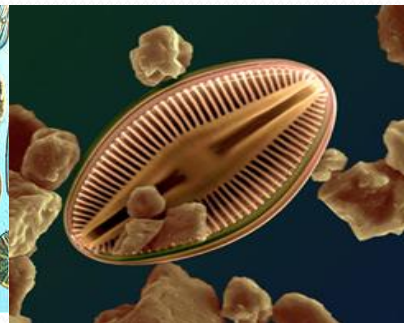
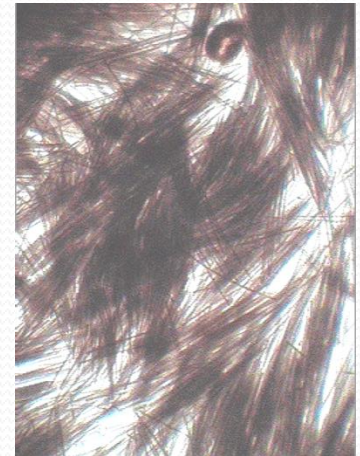
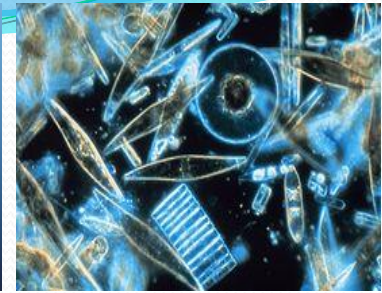
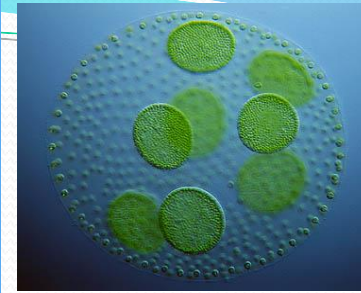
What do we need to know?

Impact on phytoplankton

Changes in the pH at the cell surface of phytoplankton could adversely affect cellular equilibrium, leading to poor growth if not death.

Plankton often grow in clumps or aggregates. But the way they are handled tends to break these clumps up if the pH reduced.

Ocean acidification could change the diversity of plankton living in the ocean, with species that can't deal with changed conditions losing out to those that can.



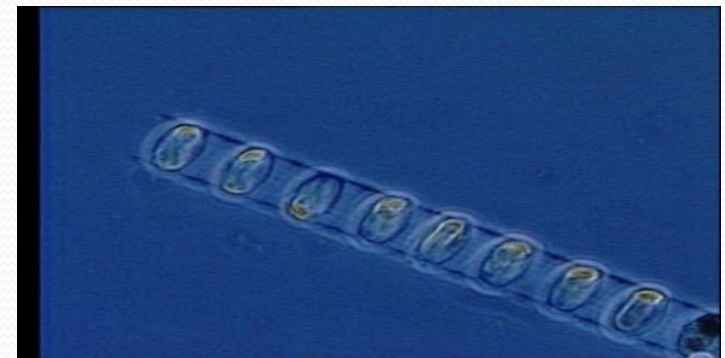
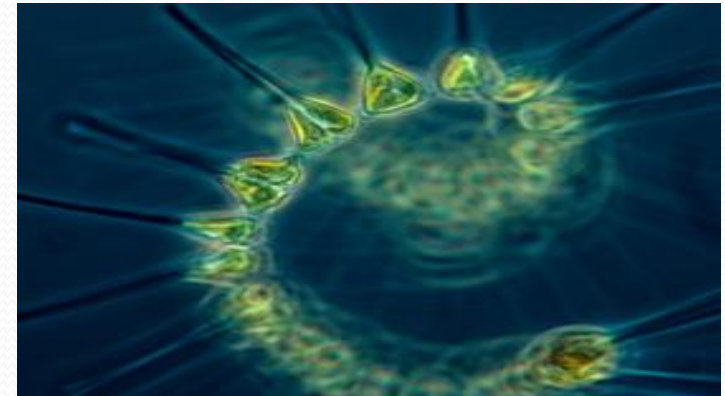
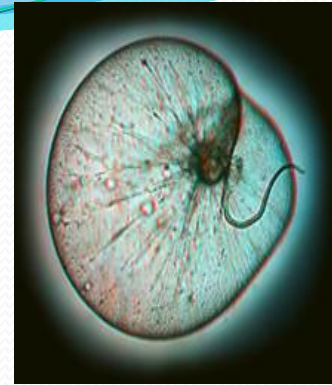
What do we need to know?

Impact on phytoplankton

The lowering pH limits for growth of the dinoflagellate.

Some phytoplankton indicate that reductions of 0.3-0.5 pH units have little impact on productivity, but may differentially impact species dominance.

Ocean acidification could increase the nitrogen fixing, photosynthesis rate and growth of some phytoplankton (Diatoms)



What do we need to know?

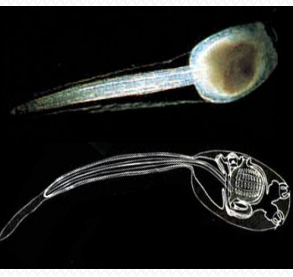
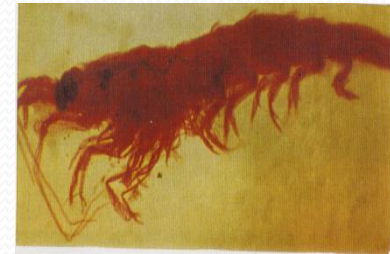
Impact on survival

Meroplankton is the most sensitive to CO₂ induced OA.

A decrease of 0.2 unit of pH induces 100% mortality in calcifying larvae such as crustaceans, molluscs and echinoderms *due to larval malformations that include skeletal defects.*

However, the low pH enhanced developmental success in calcified sea urchins and non-calcified Tunicate larvae.

Therefore profound changes in ecological relationships (*predation, competition, etc.*) is then expected



What do we need to know?

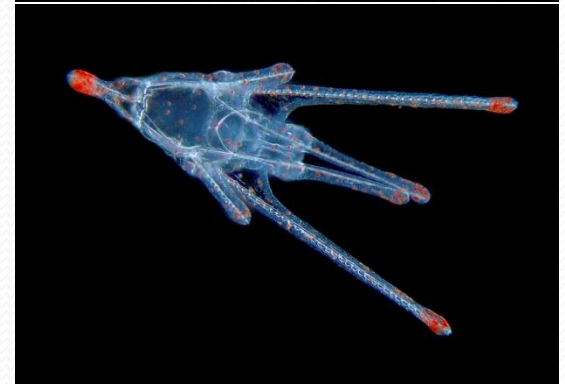
Impact on developmental dynamics

OA is reduced the developmental rate of planktonic larvae. At low pH, it takes more time to reach the same developmental stage, increasing the time taken to reach metamorphosis.

A delayed development leading to a delayed settlement can impact local populations.

Planktonic mortality is high and increasing the time a larva spends in the plankton/water column must increase the chance of loss by predation and/or by delay in the opportunity to settle.

The timing of recruitment is also crucial and late settlers often experience the lowest survival.

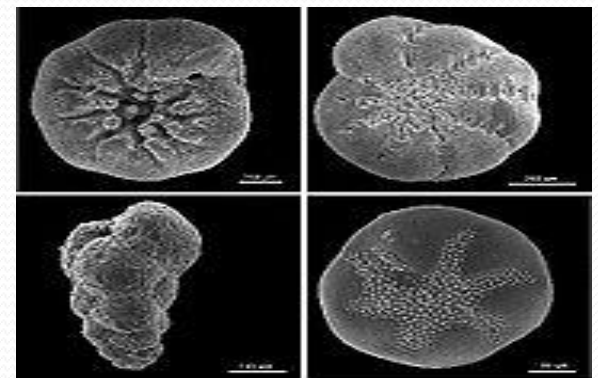
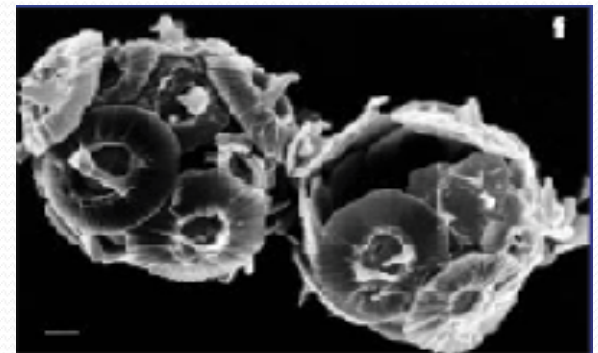
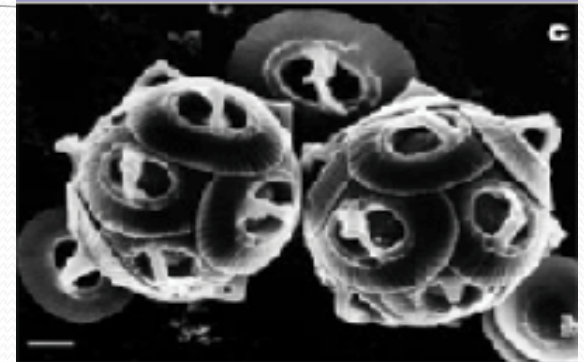


What do we need to know?

Impact on calcification

20 to 40 percent reduction in biogenic calcification of coccolithophores, resulting in malformed calcareous plates and layers of plates and lose half their protective coatings.

Planktonic foraminiferans are failed to calcify due to OA.

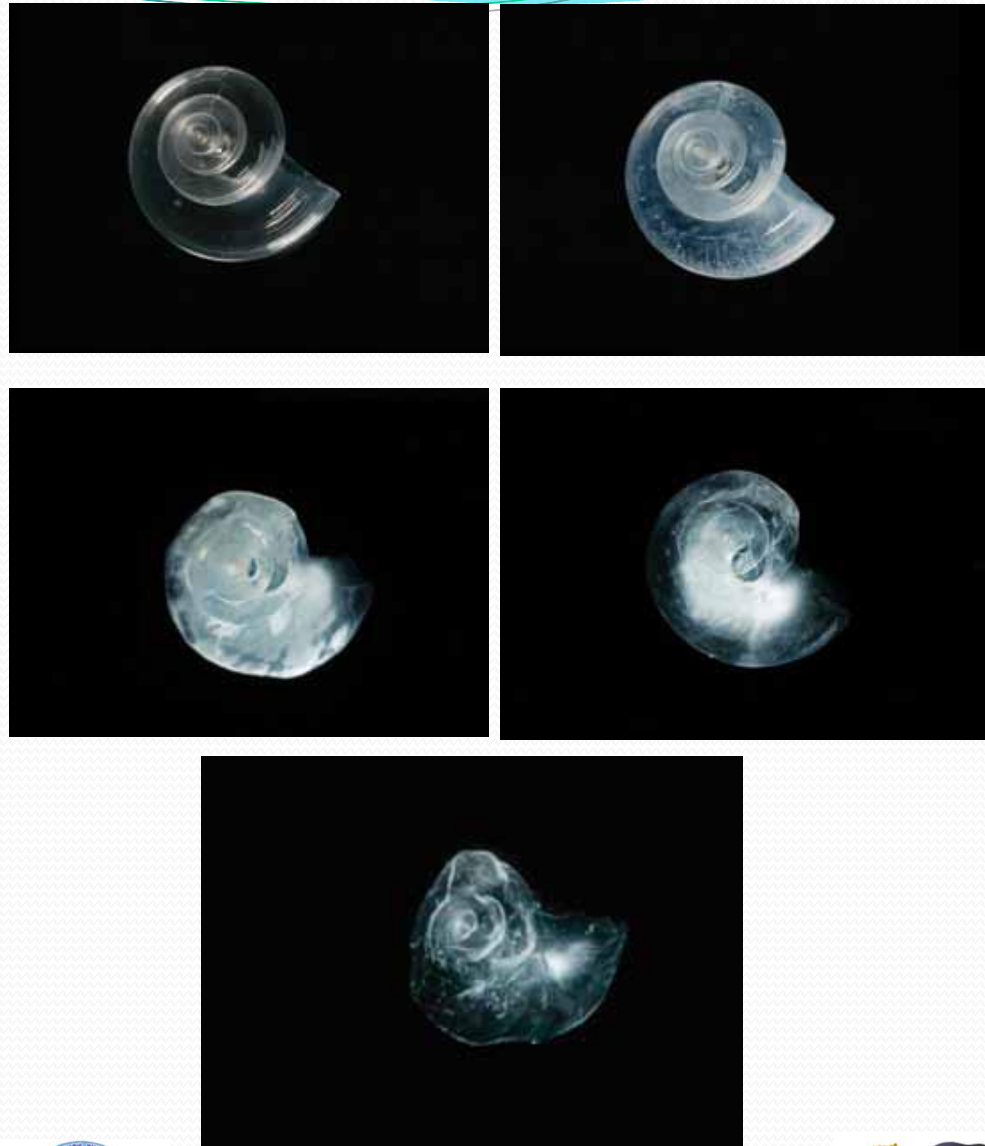


What do we need to know?

Impact on calcification

Aragonite-producing **pteropods** are a group of 32 species of planktonic snails.

Pteropods are particularly threatened by ocean acidification because of the high solubility of aragonite



What do we need to know?

Impact on physiology

Calcium and other ion-transport based phenomena are vital for many physiological processes (i.e. ciliary activity, muscle contraction, neural signalling and integration, etc.).

The larval feeding efficiency at low pH is significantly lower. The influence of OA on feeding may explain observed impacts on parameters such as survival, growth rate and other energy dependent process including calcification.

Larval plankton *have calcified skeletal rods supporting their bodies, and propel themselves with ciliated bands looped around projections called arms. Ciliated bands are also used in food capture, and filtration rate is correlated with band length. As a result, swimming and feeding performance are highly sensitive to morphological changes.*



What do we need to know?

Impact on physiology

Due to elevated level of pH, larvae developed significantly narrower bodies. Despite these morphological changes had significant effect on swimming speeds. Acidified larvae had significantly smaller larval stomachs and bodies, suggesting reduced feeding performance.

Changing ocean chemistry could turn some fish species into easy meals, with senses of smell so scrambled they're actually attracted to their predators.

Ocean acidification impairs olfactory discrimination and homing ability of a marine fish larvae.



What do we need to know?

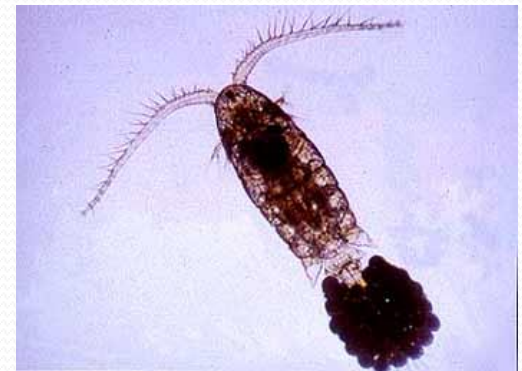
Impact on physiology

Ocean acidification showed significant **negative impacts** on **egg hatching success** and **naupliar survival** of copepod *Calanus* sp..

Ocean acidification significantly modifies the **stochastic properties of successive displacements**, leading to decrease mate encounter rates when copepods cannot rely on female pheromone plumes (i.e. under turbulent conditions)

Decreases the ability of males to detect females pheromone trails, to accurately follow trails and to **successfully track a female**. This led to a significant decrease in contact and capture rates in acidified seawater.

Ocean acidifications decreases the ability of male copepods to detect, track and capture a female, hence suggest an overall **impact on population fitness and dynamics** *E. affinis* and *T. longicornis*.



What do we need to know?

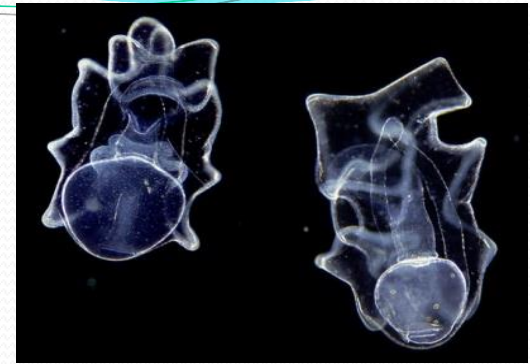
Adaptation potential

Some diatoms might be survive and produce more energy during photosynthesis.

Similarly, the feeding and respiration rate can be increased in some copepods (*Calanus sp.*) when the pH decreased.

Some copepods can also have the capacity to adapt to OA. One generation is needed to cope with impacts of OA on life cycle dynamics and second generation animals adapted to low pH (Dupont and Thorndyke, 2008).

The growth, development and survival of sea urchins, tunicate larvae and jelly fish could be increased when the pH decreased. .



What do we need to know?

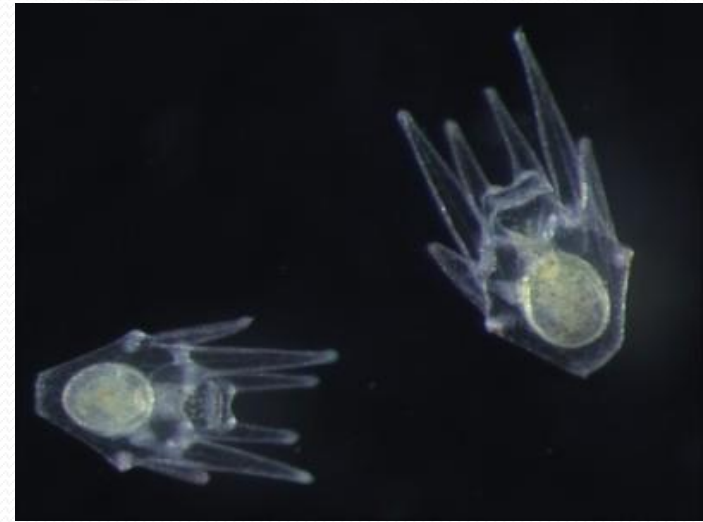
Synergistic effects with other stressors

In the future ocean, OA will operate in synergy with other anthropogenic stressors.

Predicted scenarios indicated a threat to marine life through the specific or synergic effect of both OA and temperature (global warming).

Experiments on molluscs (Parker et al., 2008) and echinoderms (Byrne and Davis, 2008; Dupont and Thorndyke, 2008; Wren et al., 2008) demonstrate that some negative impacts of OA can only be observed when combined with higher temperature (an increase of 2°C expected for the end of the century).

For example, a much higher mortality was seen in sea urchin larvae (*Strongylocentrotus purpuratus*) cultured at low pH (7.7) and at 16°C compared to the control at pH 7.7 and 14°C (Wren et al., 2008).



What do we need to know?

What are species/ecosystems tipping points?

- ❖ If we want to predict what will happen in the future ocean, we need to be able to define a reliable way to calculate species/ecosystem tipping points.
- ❖ We should not only focus on calcifying species and certainly more energy should be invested in the potential “winners” from the affects of OA and global warming. It is as important to understand why some species might benefit from OA as it is to understand why others are negatively impacted.
- ❖ For example, jellyfish appears as excellent candidates. There is some evidence (Attrill et al., 2007), although controversial (Haddock, 2008; Richardson and Gibbons, 2008), that OA, in concomitance with increasing temperature, may lead to increases in the abundance of jellyfish by the end of this century.
- ❖ However, no experimental evidence is available, in particular for the key early developmental stages. Since it is not possible to study all species and all populations, we need to understand the origin of the observed variability and apparent paradoxes (opposite effects in closely related species).
- ❖ Tipping points vary among species and we need to study the mechanisms of physiological response to understand these differences.



What do we need to know?

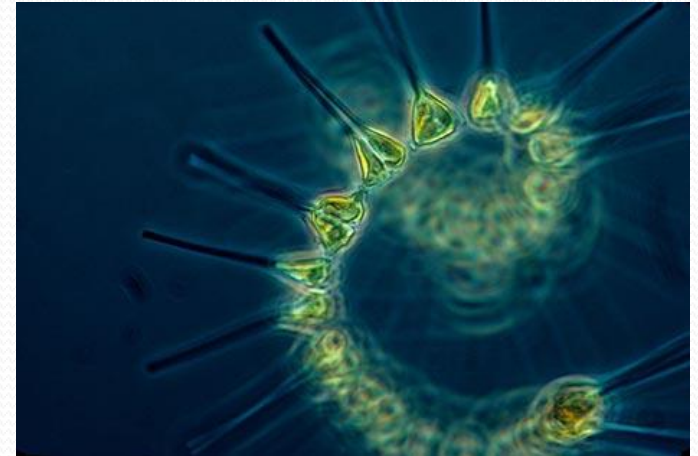
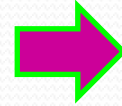
What will happen in the real world?

- ❖ In future experiments, it is essential to take into account the complete developmental cycle from egg to juvenile.
- ❖ Trophic structure and biodiversity are also key components of the resistance and resilience of marine ecosystems for future perturbations.
- ❖ When designing an experiment, we need to work in realistic conditions for both abiotic (e.g. control conditions that mimic the real local environment experienced by the larvae at the time of spawning, including natural variations of temperature, alkalinity, salinity, etc.) and biotic (e.g. density, food type and concentration).
- ❖ If ocean acidification leads to disturb on plankton can leading to a change in the composition of the ecosystem. Although plankton is important prey for higher organisms, it is not yet clear how such changes would affect marine biodiversity.

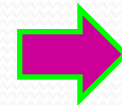


Impact of climate change driven ocean acidification on biodiversity

Changing in nitrogen and iron concentration due to acidification can leads to reduction in primary production and phytoplankton growth

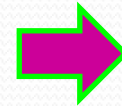


Changes in primary production can reduces the zooplankton production & growth

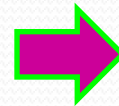


Impact of climate change driven ocean acidification on biodiversity

A decrease in plankton production, which could result from a ocean acidification, would mean less food for fish populations. In addition, OA are expected to increase in many species. And changing OA can affect the fish breeding and spawning

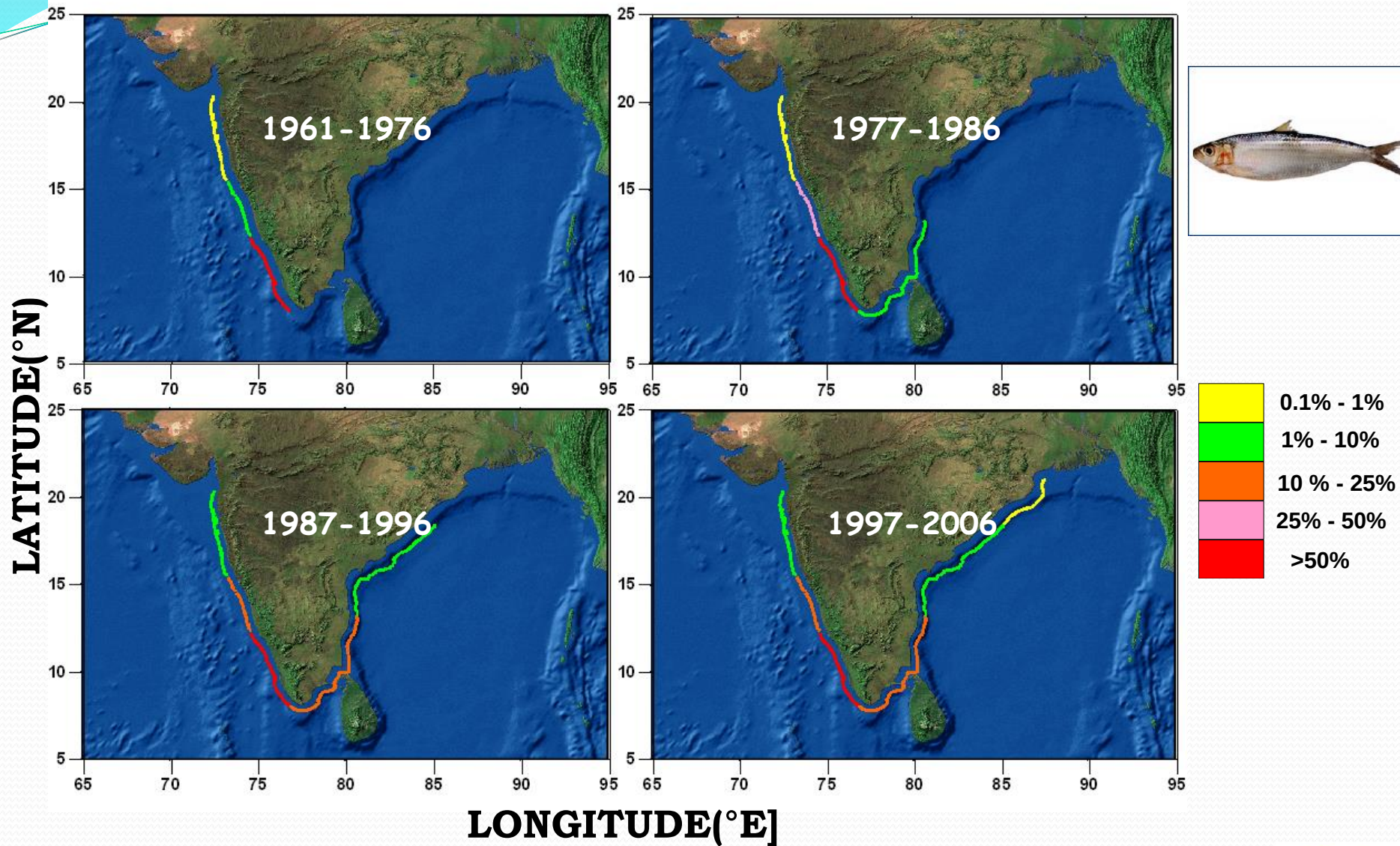


The eggs and larvae of many fish species are sensitive to OA. The naturally high mortality of fish larvae can be possible



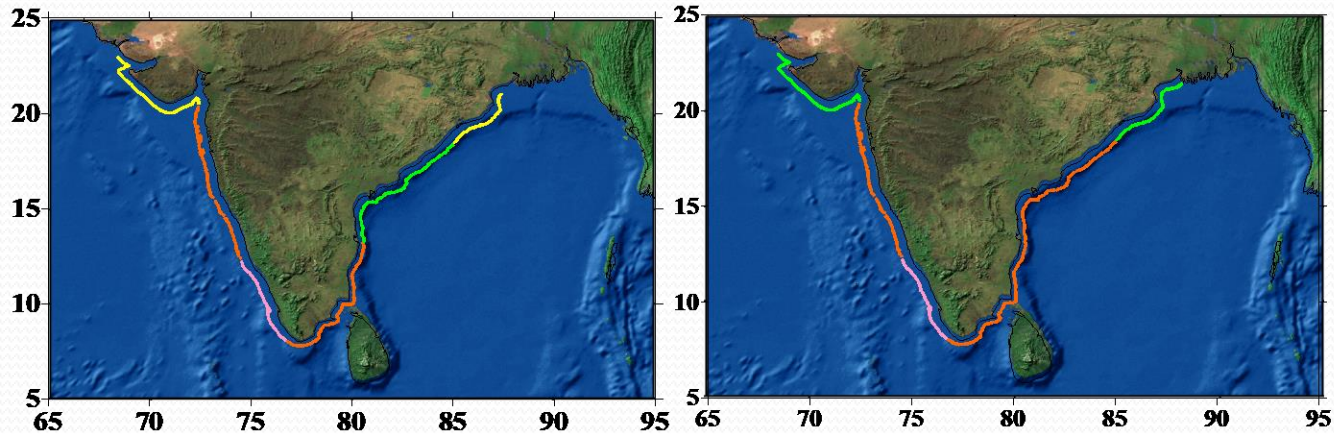
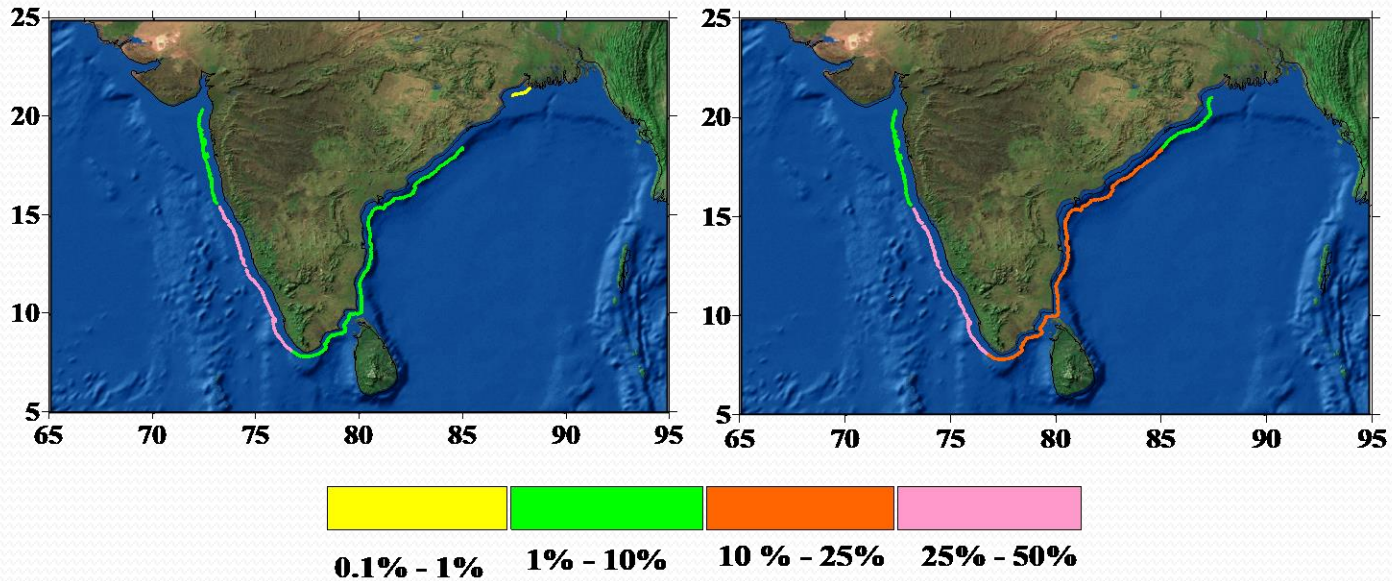
EXTENSION OF OIL SARDINE

(the colored lines indicate percentage of All India oil sardine catch)

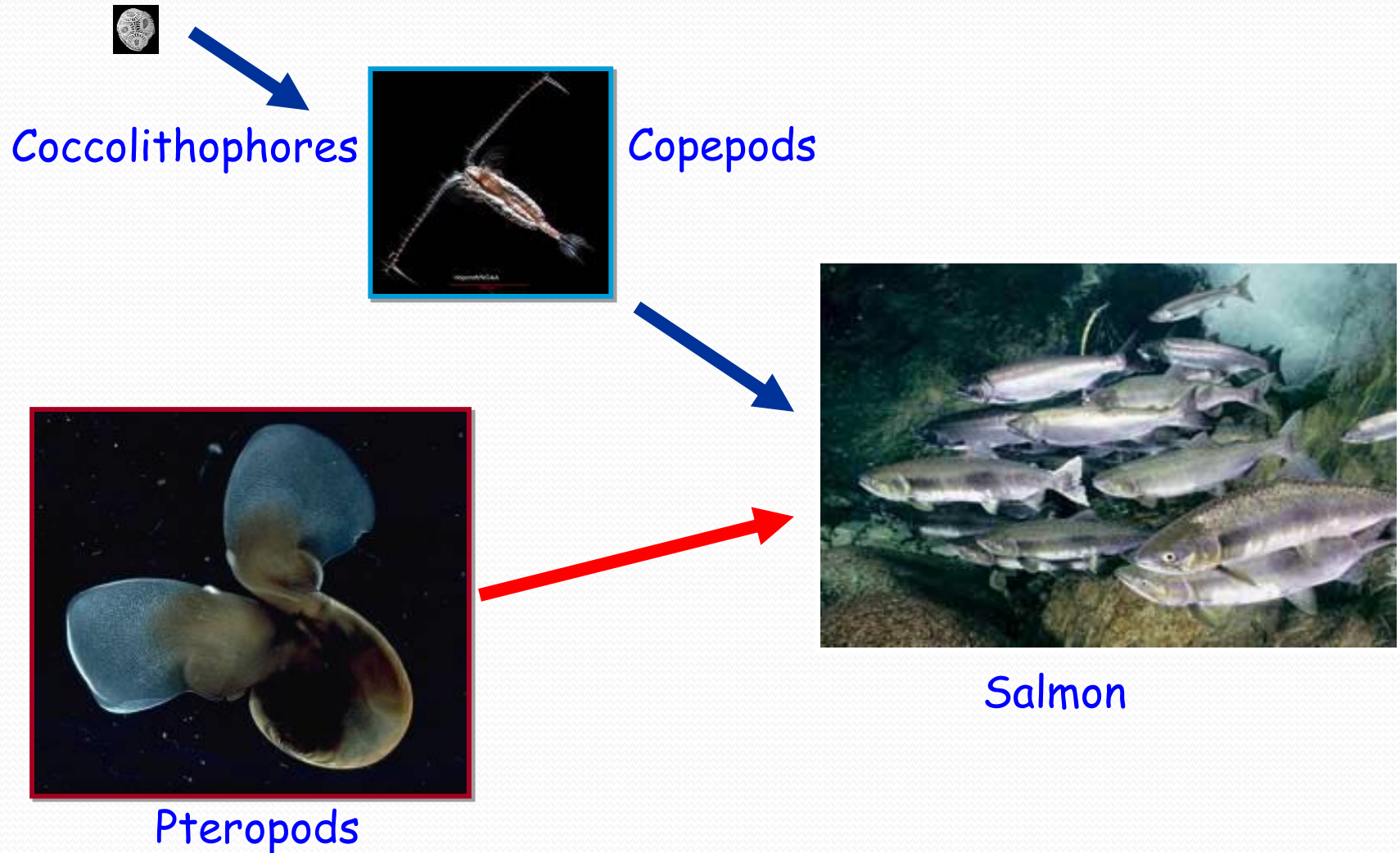


EXTENSION OF INDIAN MACKEREL CATCH

Latitude (°N)

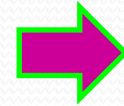


Potential Effects on Open Ocean Food Webs

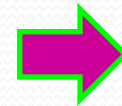


Impact of climate change driven ocean acidification on biodiversity

Many of the seabirds that prey on fish and plankton are likely to have their food supply reduced and ocean acidification can influence the breeding and nesting of seabirds.

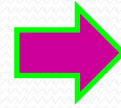


Due to glaciers melting the Penguins are facing threats due to lack of climate, habitat, foraging grounds and migration

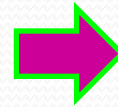


Impact of climate change driven ocean acidification on biodiversity

The predicted reduction in primary and secondary productivity that could result from increased OA would inevitably reach the top of the food web with supplies for marine mammals being affected.



Temperature increases in the Arctic have caused sea ice to break up earlier in the summer allowing polar bears less time to build up vital fat reserves to last them through the winter months. If this trend continues a decline in the weight of adult polar bears and birth rates, will become a serious threat to their survival.



What can we do?

- ❖ Today, the climate change threat has reached the public and political conscience and has become a major concern.
- ❖ OA is just another consequence of our increasing CO₂ emissions, the “global warming’s evil twin”.
- ❖ Data available so far are clear enough to demonstrate that we need to reduce our CO₂ emissions. As scientists we still have to spread the word and provide new and convincing evidence about what will happen in the near future, but maybe it is time to propose some solutions.
- ❖ In order to allow society and policy makers to address the big environmental questions, we need good quality information to predict what will happen at the local level and develop strategies to minimise impacts.
- ❖ We need to identify the species, populations and ecosystems that are most at risk and suggest some key areas for conservation efforts.



What can we do?

- ❖ We should also put some more effort into the investigation of adaptation potential, understand geographical variation in organism responses to OA and try to identify and isolate OA resistant strains/populations of keystone or economically important species.
- ❖ This approach may allow us to rescue some key ecosystems in the future ocean and help develop some sustainable aquaculture approaches.
- ❖ Another approach should be to identify refuge ecosystems with more favourable or fluctuating conditions providing some relief from unfavourable environments (e.g. regions where OA will be associated with permanent or seasonal oversaturation of calcium carbonates).
- ❖ In such approaches and ambitions, it will be essential to integrate all the environments experienced by a species during its life cycle (e.g. planktonic and benthic, meroplankton).
- ❖ Jellyfish blooms have increased over the last several decades (Purcell et al. 2007), but it is too soon to determine whether such recent jellyfish increases will persist or the populations will fluctuate with climatic regime shifts, particularly those at decadal scales, as has been observed previously.



What can we do?

- ❖ It is important to resolve possible linkages between jellyfish blooms and ocean acidification and determine whether continued changes in the seawater inorganic carbon system will exacerbate problematic increases in jellyfish that have been associated with climate change, overfishing, eutrophication, and other factors.
- ❖ Planktonic ecosystems are complex nonlinear systems, and the consequences of ocean acidification on such ecosystems are largely unknown. Substantial changes to species diversity and abundances, food-web dynamics, and other fundamental ecological processes could occur; however, the interactions and feedbacks among the effects of chronic, progressively increasing ocean acidification and other environmental variables are difficult to predict.
- ❖ Ecosystem responses will also depend on the ability of biota to adapt to seawater chemistry changes that are occurring at rates they have not encountered in their recent evolutionary history (Siegenthaler *et al.* 2005). *Future progress will likely require integrated approaches involving manipulative experiments, field observations, and models, particularly at regional scales.*



What can we do?

- ❖ *In contrast*, the potential effects ocean acidification may have for the vast majority of marine species are not known.
- ❖ Research into the synergistic effects of ocean acidification and other human induced environmental changes (e.g., **increasing sea temperatures**) on marine food webs and the potential transformative effects these changes could have on marine ecosystems is urgently needed.
- ❖ It is important to have a firm understanding of the degree to which ocean acidification influences critical physiological processes such as **respiration**, **photosynthesis**, and **nutrient dynamics**, as these processes are important drivers of **calcification**, **ecosystem structure**, **biodiversity**, and **ultimately ecosystem health**.
- ❖ Future ocean acidification research needs include **increased resources** and **efforts devoted to lab, mesocosm, and *in situ* experiments**, all of which will aid in determining the biological responses of marine taxa to increased OA.
- ❖ The effects of ocean acidification on **less charismatic species and/or species with no economic value should not be overlooked**. The biological response of marine organisms (both **commercial** and **noncommercial**) to ocean acidification will be key to making informed policy decisions that conform to sound ecosystem-based management principles.



What can we do?

- ❖ There is a critical need for well-developed spatial and temporal models that give accurate present day and future estimates of aragonite and calcite saturation states in the coastal zones.
- ❖ The shallow continental shelves are some of the most biologically productive areas in the sea and are home to the majority of the world's fisheries, but accurate carbonate saturation state data do not currently exist for most coastal regions.
- ❖ Ocean acidification information should also be integrated into existing ecosystem models, which attempt to predict the effects of environmental changes on marine populations and ecosystem structure (e.g., Ecopath and Ecosim). Development of these tools is essential to making credible predictions of future ocean acidification effects on marine ecosystems and will aid in guiding management decisions.
- ❖ Predicting the future is, at best, a highly uncertain enterprise. Nevertheless, we have a sufficient basic understanding of the ecological processes involved to claim that if humans fail change their behaviour and to reduce emission of CO₂ (and subsequent warming and OA), many species and ecosystems will experience profound modifications with severe socio-economic consequences. If only few data are available on impact of OA on early development, they clearly indicate that many species will be drastically affected.



What can we do?

- ❖ Determine the direct and indirect effects of ocean acidification on marine organisms and ecosystems.
- ❖ Develop better predictive models of ocean acidification.
- ❖ Explore and implement management options that help protect marine ecosystems from ocean acidification.
- ❖ Support ocean acidification research legislation.
- ❖ Support carbon dioxide emission reductions.



NOAA Acidification Experimental Facility



Packed Column

pH controller

Reservoir

Intrepid Biologist

Exposure Tank

CONCLUSIONS

- ✳ More funds are needed for ocean acidification research. Understanding the implications of ocean acidification will facilitate the development of strategies to counteract the detrimental impacts of ocean acidification by the scientific and management communities.
- ✳ The only long term solution to ocean acidification is a substantial reduction in carbon dioxide emissions to the atmosphere.
- ✳ It is imperative that ocean acidification research move forward while strategies to reduce carbon dioxide emissions are formulated and debated.



Suggestion to policy makers

- Establishing more Protected Areas
- Establishing more Marine Biosphere Reserves
- Establishing Gene Bank and DNA Storage
- Establishing Aquariums
- Restoration of Endangered species
- Ecotourism & Restoration of Bioshield
- Public Awareness & Incentives
- Developing the alternate energy fuels
- Regular monitoring and survey of resources
- Conservation of Keystone Resources & Species
- Regular Environmental Impact Assessment
- Research Programmes
- Fellowship , Awards and Recognition
- Centers of Excellence
- Develop strict laws to limit the environmental pollution.
- Alternate livelihood through banking and subsidies.
- Identify the endangered species and controlling use of the species.
- Develop the technology for utilization of non edible fishes for sustainable utilization.
- Increased the aquaculture production.
- Develop the technology for culture of non-cultivable species.



Suggestion to policy makers

Biodiversity Forecast

- ❖ Select a specific definition of biodiversity.
- ❖ Evaluate models before using them.
- ❖ Account for multiple causes of changes in biodiversity.
- ❖ Obtain good information and make better use of it.
- ❖ Use the Quaternary fossil record to understand mechanisms that preserve biodiversity, and use these in forecasting models.
- ❖ Improve widely used modelling methods.
- ❖ Improve ecological principles embedded in general atmosphere-ocean-biotic coupled circulation models.
- ❖ Develop better models for forecasting total biodiversity.



SUGGESTION TO STAKEHOLDERS

- ❖ Deforestation and conversion of crop land should be stopped.
- ❖ Chemical and pesticides should be controlled by replacing by organic fertilizers.
- ❖ Industrial and domestic wastes should be properly treated before discharges into the sea or river.
- ❖ CRZ Act must be followed when establishing the road, restaurant, commercial shops and residential building.
- ❖ Dredging and mining activities should be avoided at or nearby sensitive ecosystems.
- ❖ Dumping of ship wastes, plastics, oil and toxic substances into the sea should be stopped.
- ❖ Do not cut the mangroves & Don't allow the cattle grazing in mangrove forest.



RECOMMENDATIONS

- ❖ So far, surveys and inventorization have been conducted only in selected areas and only on major commercial species. So complete survey on all flora and fauna is needed.
- ❖ There is demand for Taxonomist. So expertise in taxonomy should be appointed and youngsters should be encouraged for taxonomical investigation.
- ❖ Biodiversity and Taxonomy is being taught as subject in the curricula of school and undergraduate level.
- ❖ The separate courses should be started in undergraduate and postgraduate level on Biodiversity and Conservation.
- ❖ More employment & Research opportunities should be created to who study Marine Science, Marine Biology, Marine Biodiversity & Oceanography



RECOMMENDATIONS

- ❖ The effective management and conservation programmes is highly essential.
- ❖ To involve public, better awareness programmes are the need of the hour.
- ❖ The stakeholders should be involved in sustainable utilization of marine resources.
- ❖ Conservation of nature and natural resources must be followed.
- ❖ Fisherman's and other stakeholders should be involved in other alternate livelihood for better conservation.
- ❖ The individual and groups must involves in restoration of plants to reduce the carbon level in the atmosphere.
- ❖ Home gardening and roof gardening can be helpful to solve climate change related issues followed by biodiversity conservation.
- ❖ Use of arid salt land for salt tolerant crop and bio-shield should be practiced.
- ❖ Microalgae culture on house roofs and coastal areas are considered to be a potential remedial measures for better biodiversity conservation.



How do meet the challenge?

Avoid past mistakes

Ambitious implementation of the conservation policies

Greening of the environment

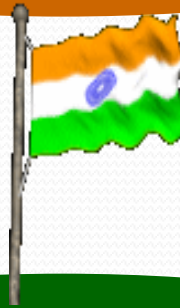
Eliminating marine pollution

Fighting climate change & Ocean Acidification



How do meet the challenge?

We need political will
and ambition!



We need to go from
words to action for true
conservation!





SAVE OCEAN SERVE NATION

**BIODIVERSITY IS LIFE
BIODIVERSITY IS OUR LIFE**

Thanks

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