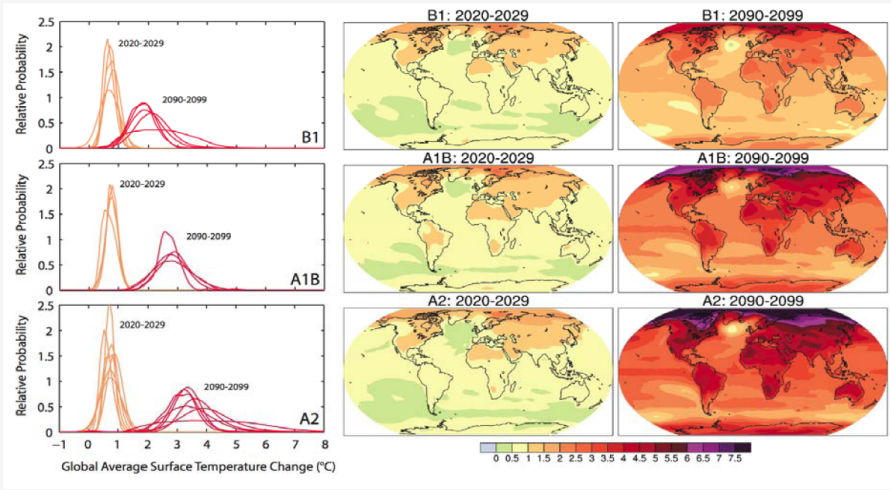
Plankton changes in the future

Earth Systems Changes

Modelling temperature changes



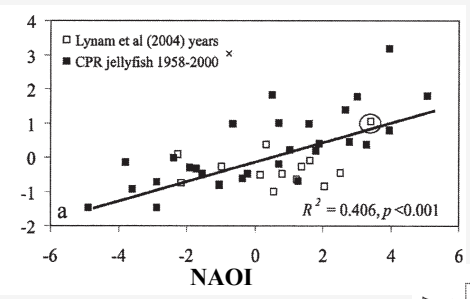
IPCC WG1 AR4

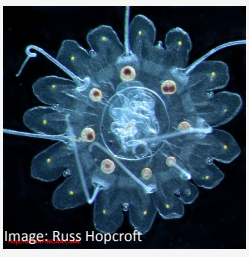
Plankton Changes

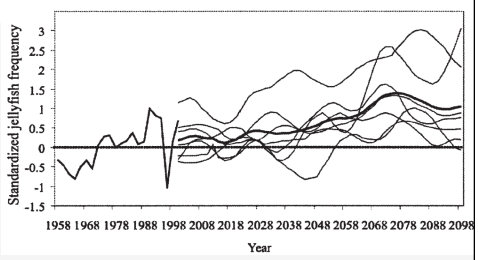
- **Issues**
  - What groups do we think will be most sensitive?
  - Where do we have sufficient empirical or process-based understanding?
- **Modelling: can we predict the changes?**
  - Empirical models
  - BGC and NPZ models
  - *Detailed population models (e.g. C. finmarchicus)*
  - *Ecosystem models*

Plankton Changes

1. Empirical Models - North Sea



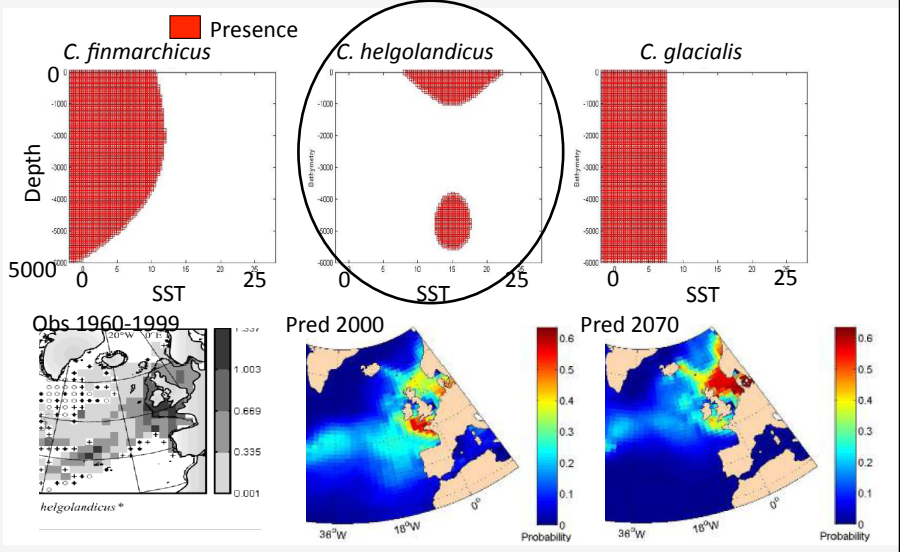




Attrill et al. (2007) L&O

Plankton Changes

2. Bioclimate Modelling – NE Atlantic

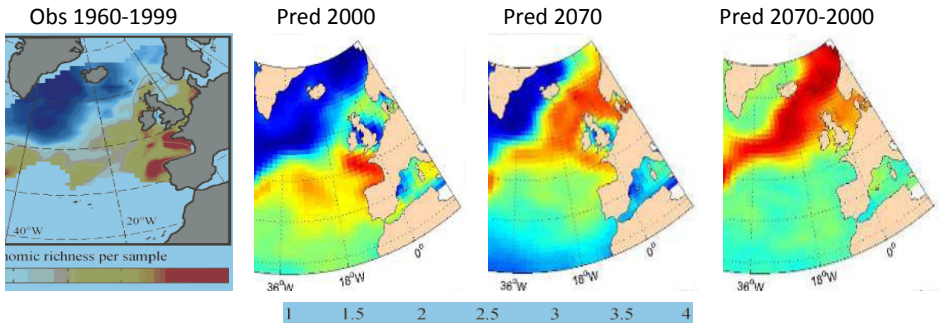


Richardson et al (unpublished)

Plankton Changes

2. Bioclimate Modelling – NE Atlantic

- 111 phyto- and zooplankton spp for diversity

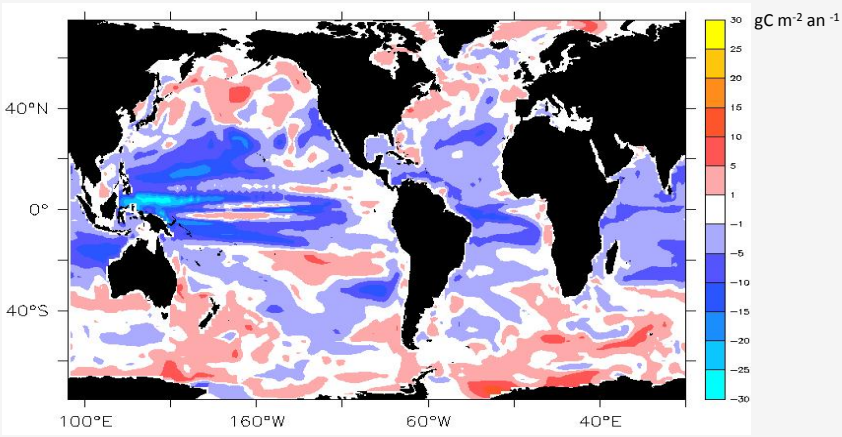


Beaugrand et al (2000) MEPS

Richardson et al (unpublished)

Plankton Changes
3. NPZ Modelling

Primary Production, 2 x CO_2 – 1 x CO_2

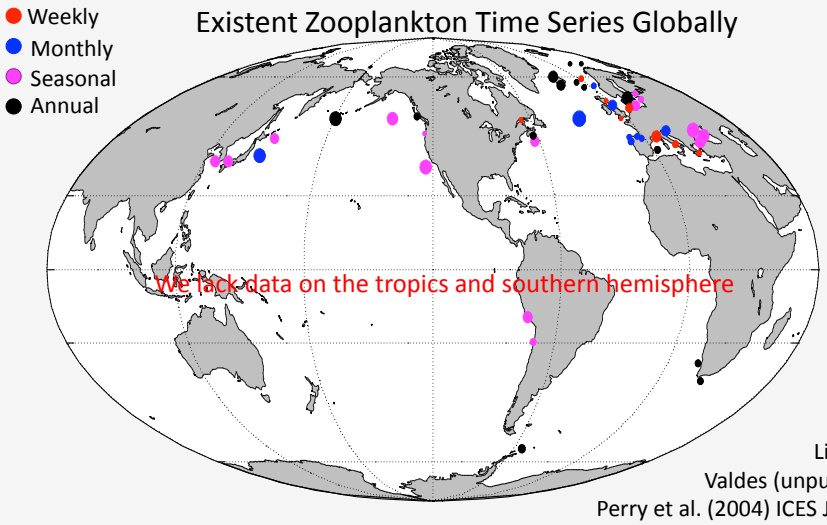


Advantage of lower trophic levels

Bopp (2005)

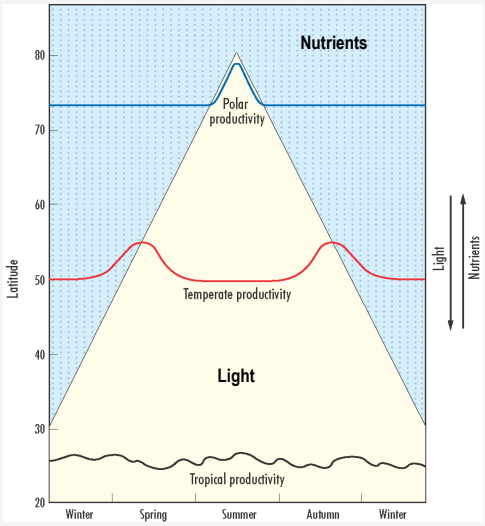
Key Challenges
We lack basic information

Existent Zooplankton Time Series Globally



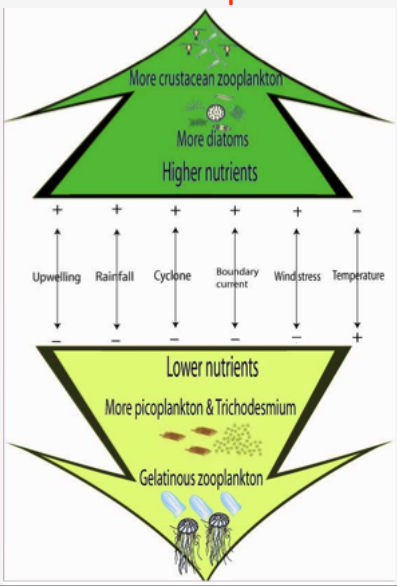
Literature
Valdes (unpublished)
Perry et al. (2004) ICES J Mar Sci
COPEPOD Database (O'Brien 2005)

Key Challenges
Response of tropical systems?



Mann & Lazier (1996)

Key Challenges
1. Response of tropical systems?

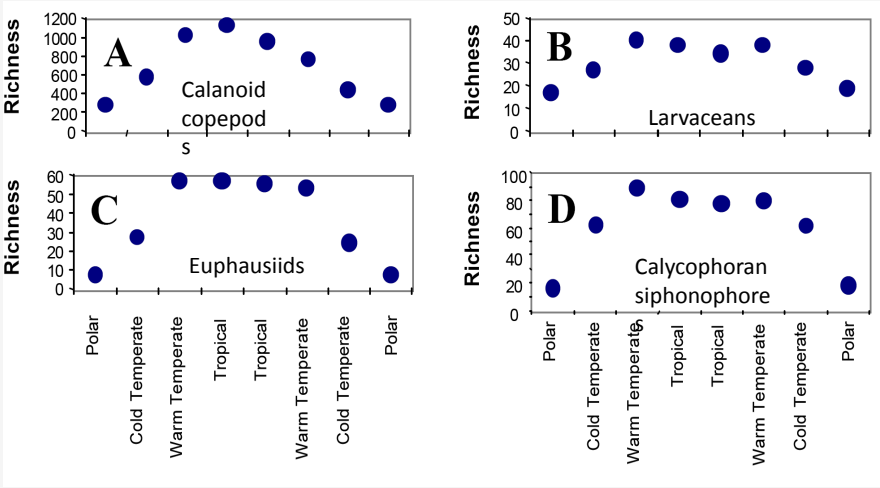


1. Expect little phenological changes in tropical systems
2. Maybe greatest influence will be changes in nutrient enrichment, which is critical to tropical systems, and this will manifest in terms of community changes

Image: Russ Hopcroft

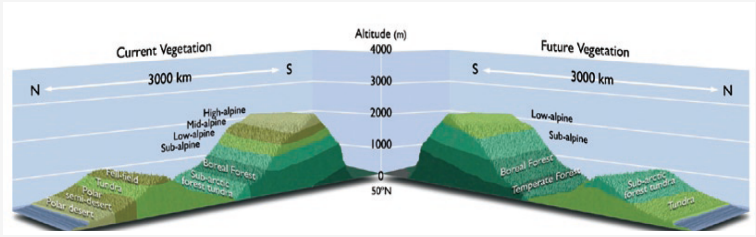
McKinnon et al (in press) GBR Book

Key Challenges
Understanding Drivers of Diversity



Gibbons et al (unpub data)

Key Challenges
Vertical distribution

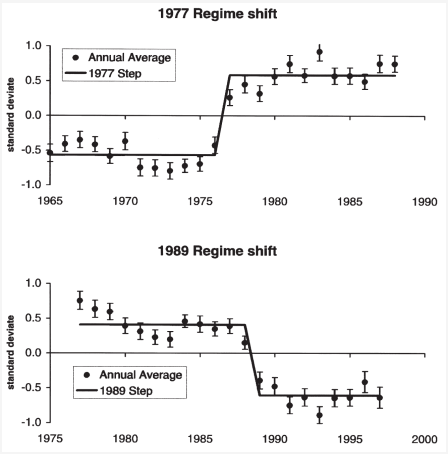


- Is there evidence for zooplankton going deeper in water column?

WWF (2006)

Key Challenges
Non-linear Dynamics

North Pacific

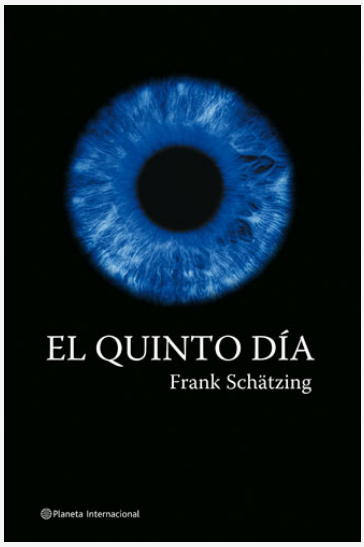


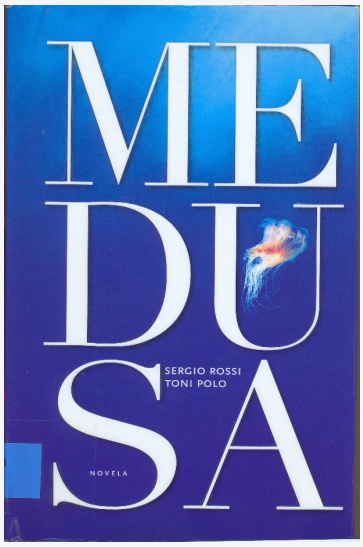
Hare & Mantua (2000) PinO
Scheffer & Carpenter (2003) TREE

Conclusions

- Dramatic impacts of climate change on plankton causing ecosystem-wide consequences
- Exciting time for long-term zooplankton research
- Increasing use of modelling approaches to peer into the future

So, what about the future?





Jellyfish blooms: are populations increasing globally in response to changing ocean conditions?

Claudia E. Mills
Friday Harbor Laboratories and Department of Zoology, University of Washington, 620 University Road, Friday Harbor, WA 98250, U.S.A.
E-mail: cemills@u.washington.edu

Key words: biodiversity, Cnidaria, Ctenophora, hydromedusae, nonindigenous spec
siphonophore

Review

Cell

The jellyfish joyride: causes, consequences and management responses to a more gelatinous future

Anthony J. Richardson[1,2,3], Andrew Bakun[4], Graeme C. Hays[5] and Mark J. Gibbons[6]

ICES Journal of Marine Science Advance Access published January 24, 2008

Enhancement of jellyfish (*Aurelia aurita*) populations by extensive aquaculture rafts in a coastal lagoon in Taiwan

Wen-Tseng Lo, Jennifer E. Purcell, Jia-Jang Hung, Huei-Meei Su, and Pei-Kai Hsu

PERGAMON

Deep-Sea Research II 50 (2003) 2473–2498

DEEP-SEA RESEARCH
Part II

www.elsevier.com/locate/dsr2

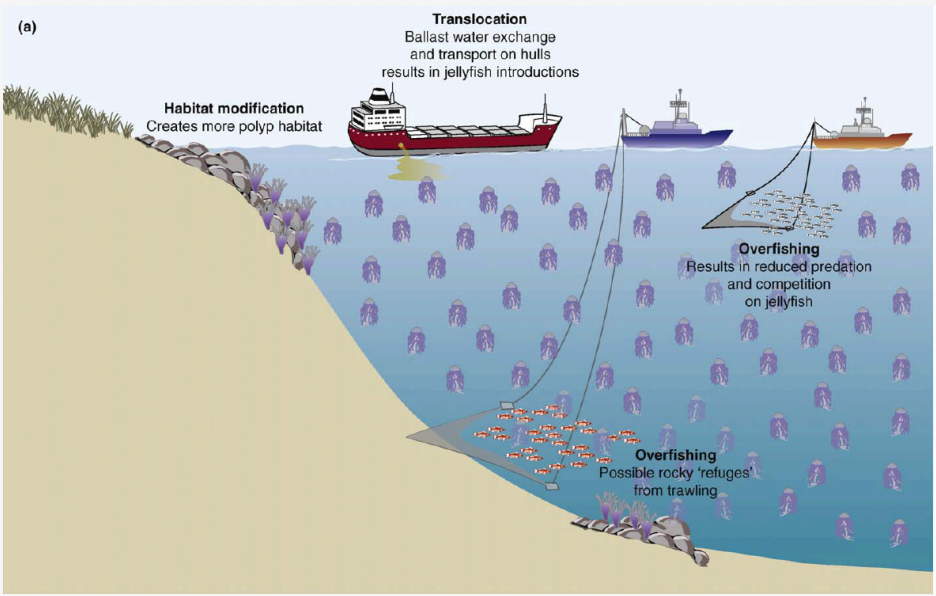
Long-term changes in pelagic tunicates of the California Current

Bertha E. Lavaniegos[a,b,*], Mark D. Ohman[a]

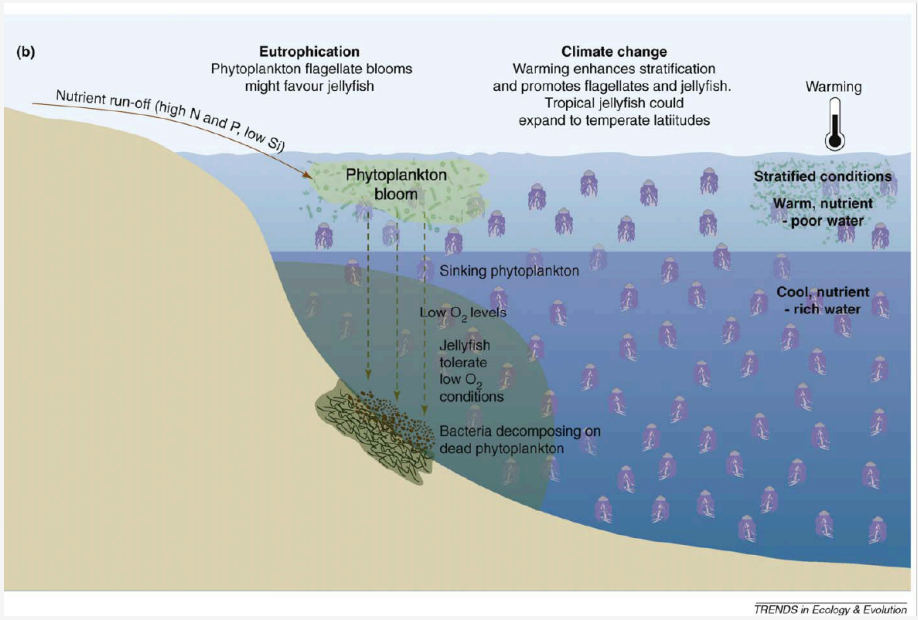
Limnol. Oceanogr., 52(1), 2007, 480–485

Climate-related increases in jellyfish frequency suggest a more gelatinous future for the North Sea

Nomura's Jellyfish
Nemopilema nomurai



Richardson et al. 2009



Richardson et al. 2009

Also aquaculture

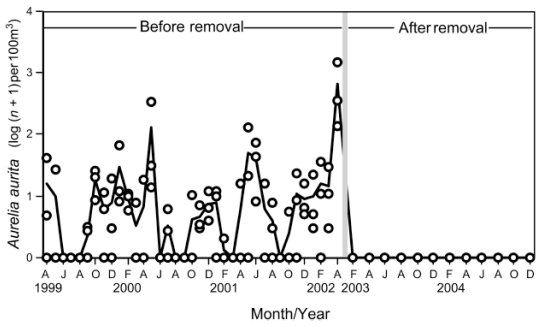


Figure 2. Jellyfish (*Aurelia aurita*) abundance in Tapong Bay, southwestern Taiwan, from August 1999 to December 2004. Samples were collected on a bimonthly schedule (February/April/June/August/October/December). Extensive aquaculture rafts were removed in the second half of 2002, as indicated by the vertical grey line. Station locations are marked by squares in Figure 1.

Lo et al. 2008

Back to the future?

Richardson et al. 2009

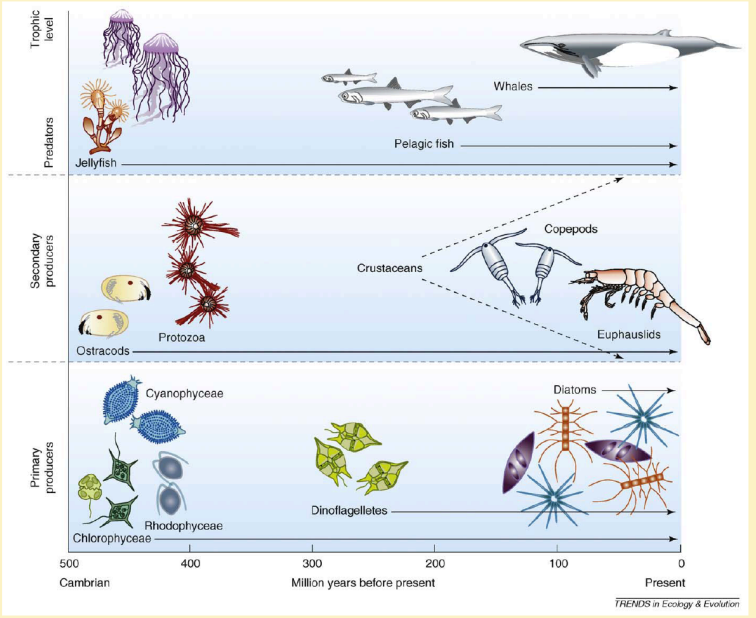
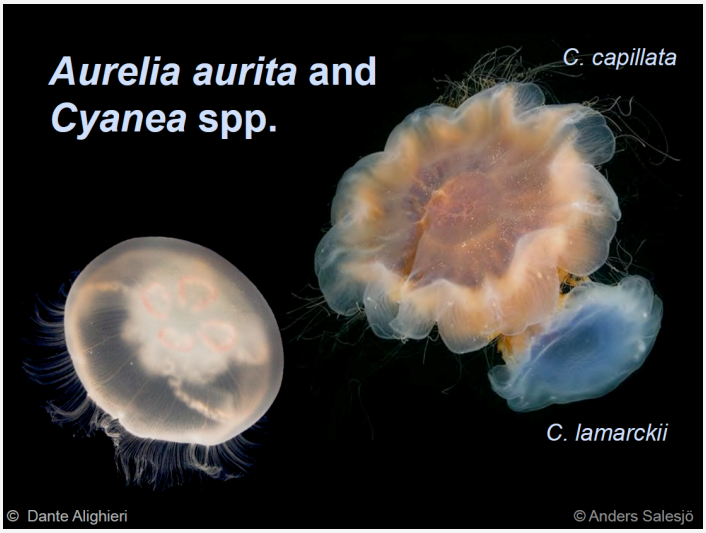
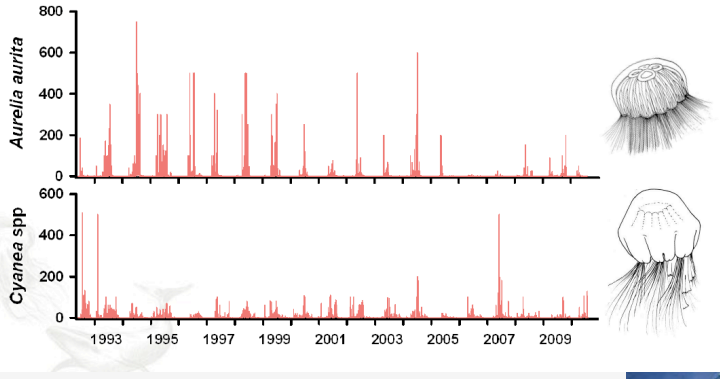


Figure I. The evolution of pelagic food chains from the Cambrian (simple food chains, with jellyfish as the top predators) to the present (more-complex food chains, with fish and higher animals as top predators). Redrawn, with permission, from Ref. [26].

Not always just increase in abundance, also species replacement



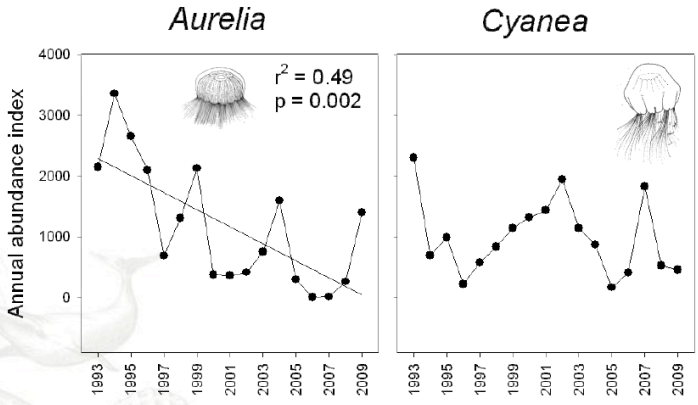
Daily observations



Hosia et al. 2011 PICES meeting

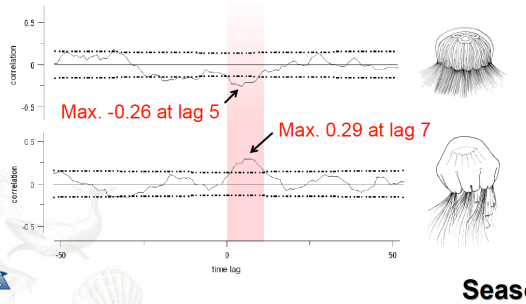
Index of annual abundance

span * % pos. obs. * average pos. obs.



Hosia et al. 2011 PICES meeting

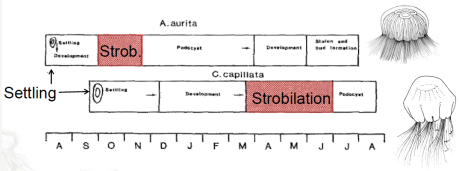
Abundance index vs. T anomaly
crosscorrelations



Temperature seems relevant

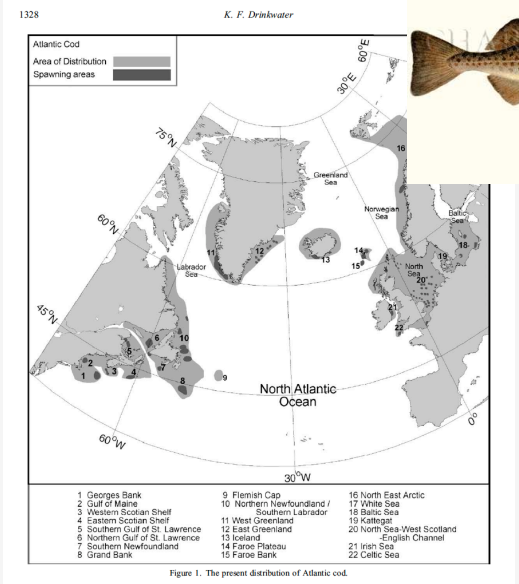
Although maybe the effect of temperature is more relevant on different stages of the life cycle

Seasonal development of polyps



Set seasonality – varies between populations

REGARDING FISH



Drinkwater 2005

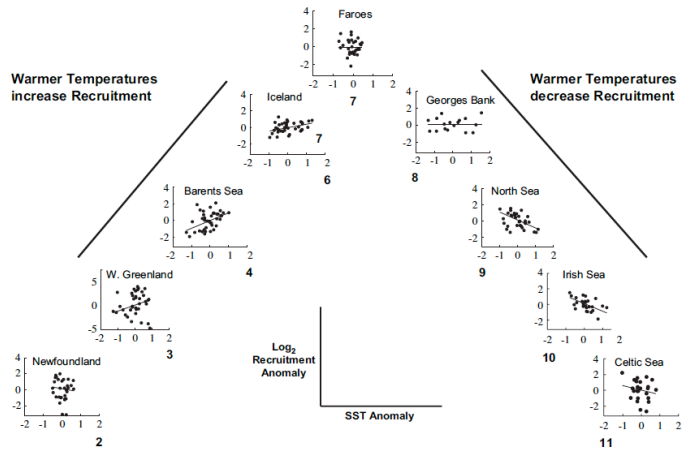


Figure 2. The relationship between the $\log_2$ of the recruitment anomaly and sea surface temperature (SST) anomaly in °C for various cod stocks. The large axis in the bottom centre of the diagram shows the axis legends for all of the plots. The numerical value at the bottom of each plot represents the mean annual bottom temperatures for the stocks. Note that stocks are plotted with bottom temperature increasing to the right. For the cold-water stocks, the SST-recruitment relationship is generally positive while for the warm-water stocks it is negative. There is no relationship in the mid-temperature range. Modified from Planque and Frédou (1999).

Drinkwater 2005

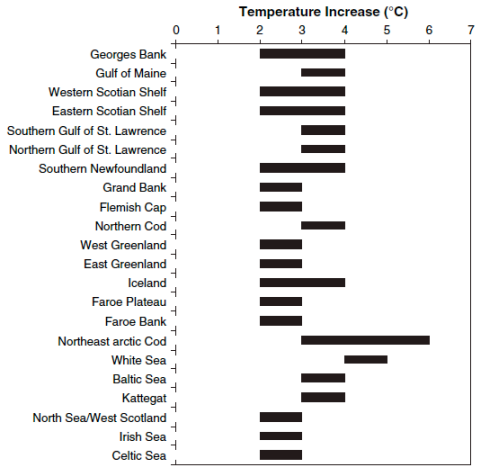


Figure 3. The anticipated range of the increase in the annual mean temperatures by the year 2100 in the continental shelf waters occupied by cod for different stocks, based on the multi-model results published by the IPCC (2001). The location of the cod stocks is given in Figure 1. Note, Northern cod is stock 10 in Figure 1.

Drinkwater 2005

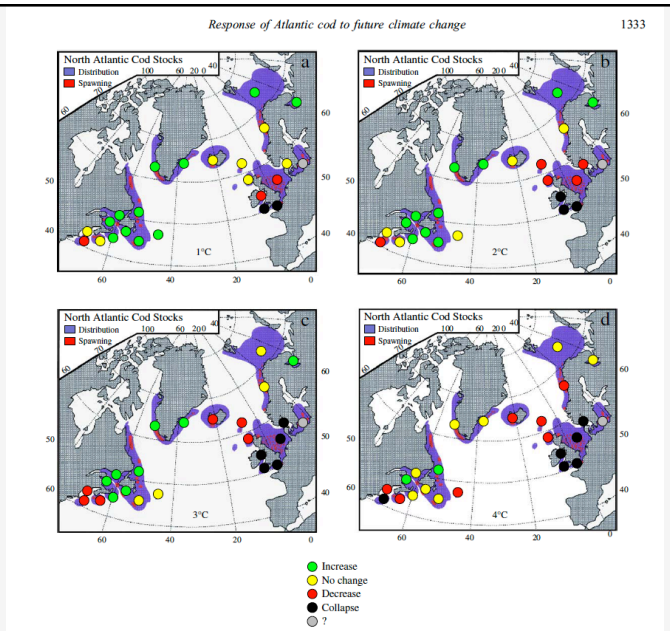
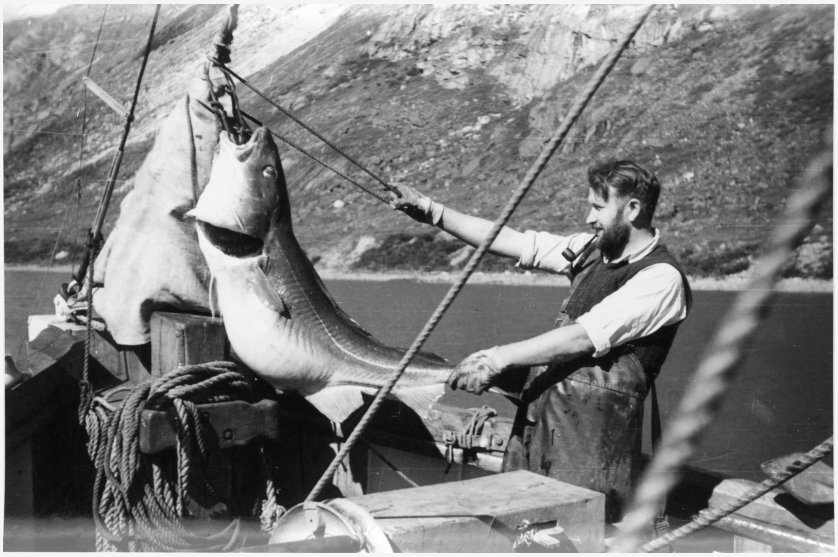


Figure 5. Expected changes in the abundance of the cod stocks with a temperature increase of (a) 1 °C, (b) 2 °C, (c) 3 °C, and (d) 4 °C above current levels.

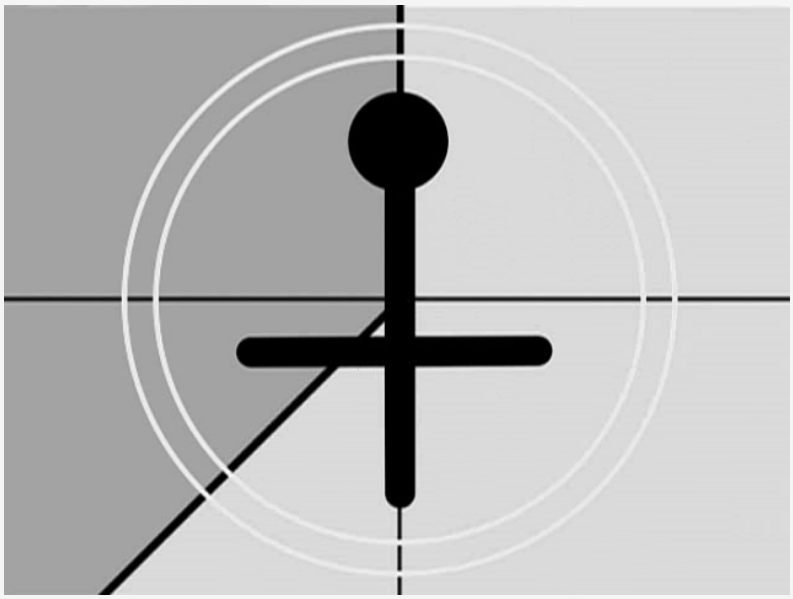
Drinkwater 2005

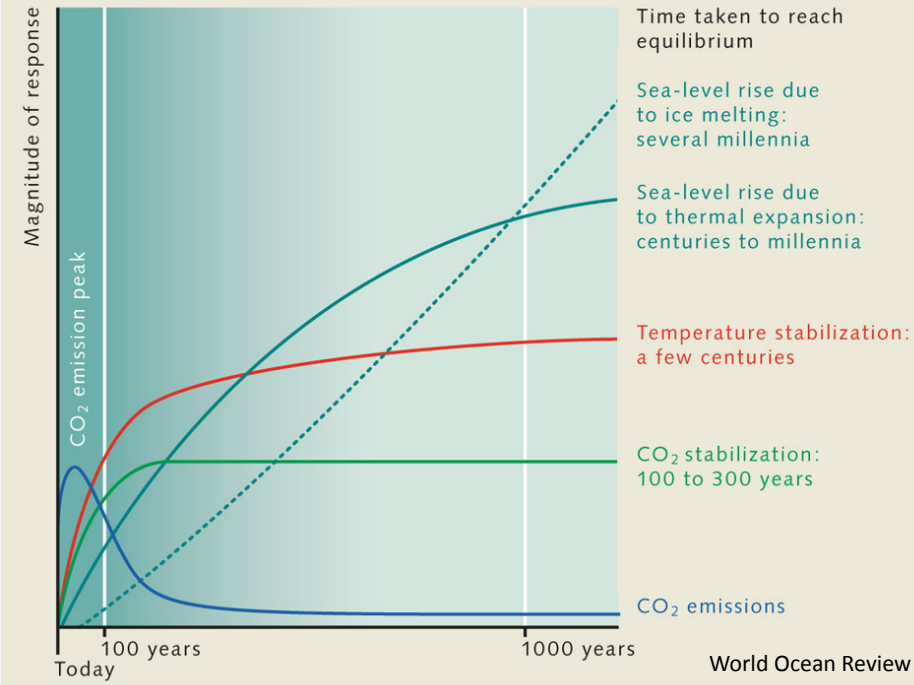


Difficult to recover

What can we do?

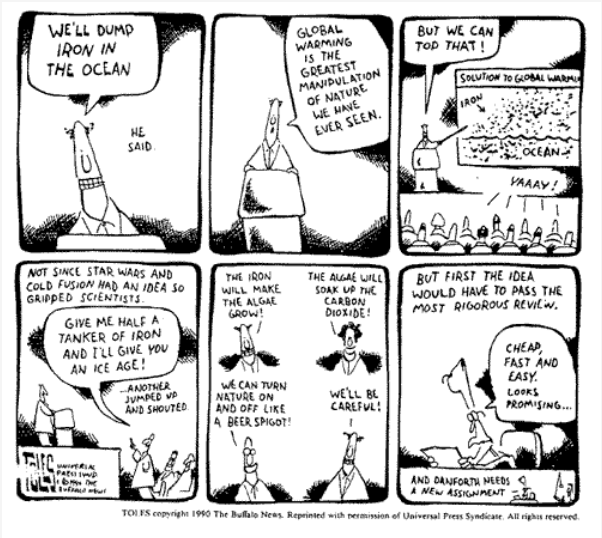
Global Warming Remedies



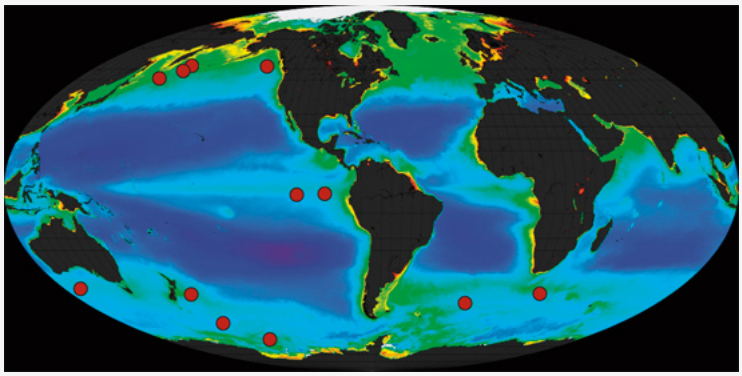


There are many different solutions proposed, some quite crazy, but there is especially one that involves plankton

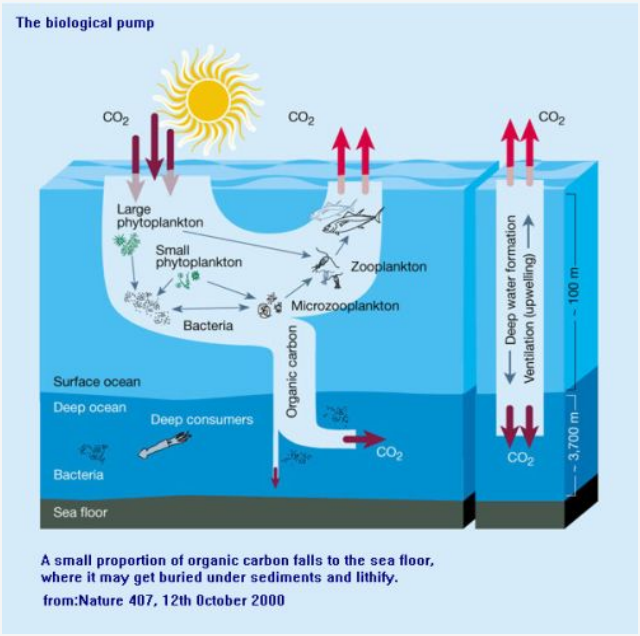
IRON FERTILIZATION EXPERIMENTS

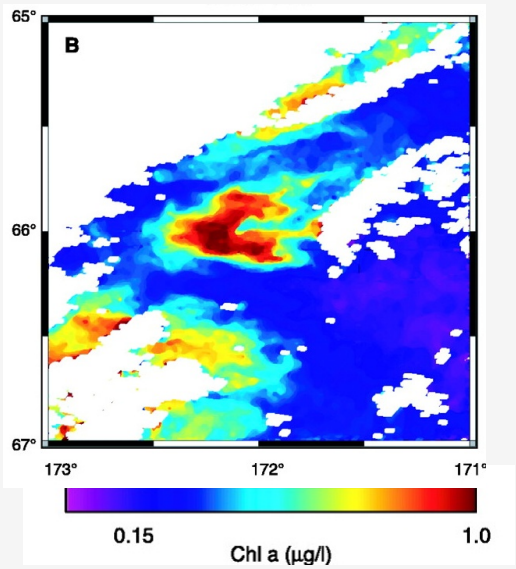


IRON FERTILIZATION EXPERIMENTS



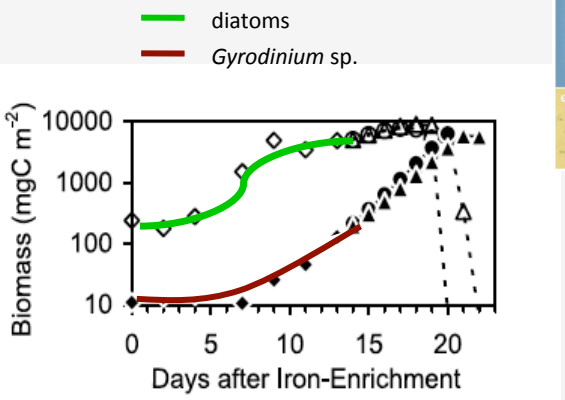
THE IDEA IS SIMPLE

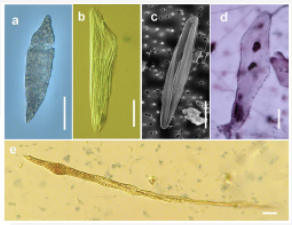




SOFeX-N northern Southern Ocean (the ocean around Antarctica)

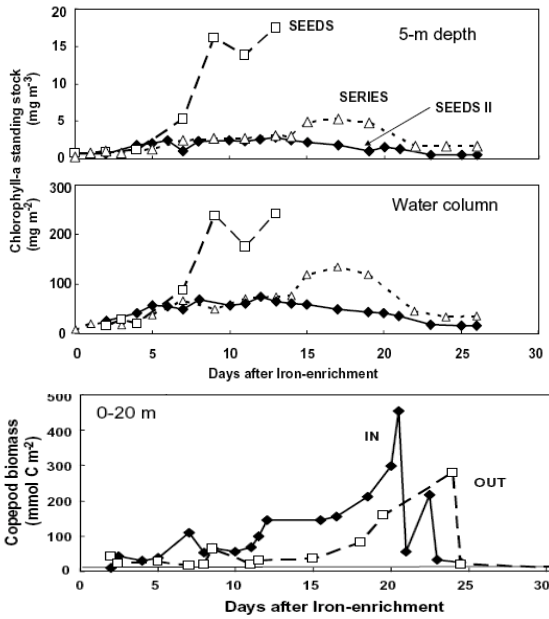
HNLC western subarctic Pacific Iron Fertilization Experiment (SEEDS 2001)

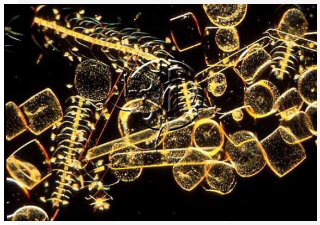




Saito et al. 2006

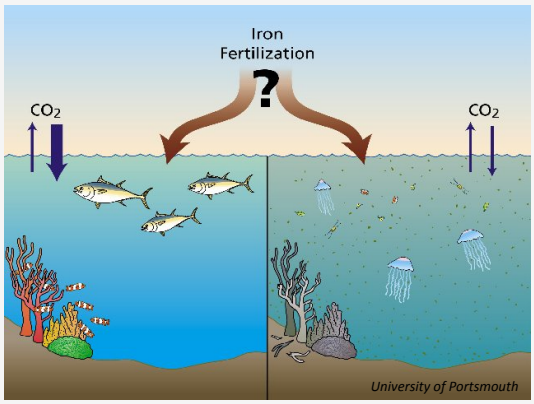
But in SEEDS II (2004)…





41

Highly unpredictable



- The amount of CO_2 secreted was actually little (a good portion of carbon was respired within the area
- It may result in HABs
- Severe ecosystem alterations (we may end up with jellyfish)
- It may result in eutrophication and further in anoxia
- There are other greenhouse gasses besides CO_2

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Published online 26 September 2007 | Nature | doi:10.1038/news070924-8

News

Mixing the oceans proposed to reduce global warming

Could nutrients from the deep help remove carbon dioxide from the air?

Quirin Schiermeier

Some coastal regions have natural upwelling, where nutrient-rich bottom waters surge to the top to feed local plant life. *JPL / NASA*

Could mighty pumps be installed in the ocean to mix up the waters and cool the planet? At least some scientists and businessmen believe so — but the idea is controversial.

In a letter to the editor published in *Nature* this week[1], James Lovelock and Chris Rapley suggest that this *deus ex machina* could be an "emergency treatment for the pathology of global warming". Large vertical pipes could, they say, be used to mix nutrient-rich waters from hundreds of metres down with the more barren waters at the surface. This could cause algal blooms at the surface, which would consume carbon dioxide (CO_2) through photosynthesis. When the algae die, some of this carbon could sink into deep waters. The algae may also produce chemicals that spur cloud formation, further cooling the planet.

Correspondence

Nature **449**, 403 (27 September 2007) | doi:10.1038/449403a; Published online 26 September 2007

Ocean pipes could help the Earth to cure itself

See associated Correspondence: Shepherd *et al.*, *Nature* **449**, 781 (October 2007)

James E. Lovelock[1] & Chris G. Rapley[2]

1. Green College, University of Oxford, Woodstock Road, Oxford OX2 6HG, UK
2. Science Museum, Exhibition Road, South Kensington, London SW7 2DD, UK

Friday 29 April 2011

The Telegraph

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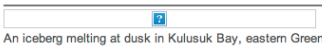
Earth News

Global warming 'cure' found by scien



An iceberg melting at dusk in Kulusuk Bay, eastern Greenland

By Charles Clover, Environment Editor 5:30PM GMT 07 Nov 2007

26 Comments

A "technical fix" that could stop global warming by taking billions of tons of carbon dioxide out of the atmosphere and save the coral reefs from being destroyed by acidification has been developed by scientists.

The deceit behind global warming
Climate change is like 'World War Three'

The process could be used on an industrial scale to remove excess carbon dioxide caused by the burning of fossil fuels from the atmosphere in "a matter of decades rather than millennia," according to researchers from Harvard and Penn State universities.

The process relies on speeding up a process that happens naturally, whereby carbon dioxide dissolved in sea water breaks down volcanic rock and soils to make alkaline carbonic salts.

The water flows into the ocean and increases its alkalinity. Sea water containing more alkali can absorb more carbon, so more carbon from the atmosphere is "locked up" and becomes harmless bottom sediments, according to the journal Environmental Science and Technology.

Researchers estimate that it would take a cube of volcanic rock 10 kilometres across to return the concentration of carbon dioxide in the Earth's atmosphere to pre-industrial levels.

Unlike other proposed "technical fixes" that "sequester" carbon dioxide from the atmosphere, this one makes the sea more alkaline and therefore counteracts the other side effect of more carbon dioxide entering the atmosphere - the acidification of the sea.

The alkalinity of the sea has remained the same for 60 million years but the burning of fossil fuels has caused it to decrease.

Greetings! [Log in] [R

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Should We Inject Carbon Dioxide into the Deep Ocean?

Posted by Will Ramos on Tuesday, January 5th, 2010 at 1:04 pm
Filed under: Discovery,News & Resources

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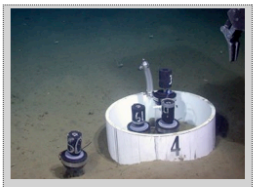
Study finds that some seafloor life may be harmed by high CO2 levels



(Click to enlarge image) WHOI scientist Joan Bernhard and colleagues from MBARI and WHOI tested whether a proposed method to remove excess carbon dioxide from the atmosphere and sequester it in the deep sea would damage single-celled benthic organisms called foraminifera. Using a remotely operated vehicle, the scientists pushed specially-constructed cylinders into seafloor sediments more than 3,000 meters (9,000 feet) deep in Monterey Bay, Calif. They directly injected a CO2 hydrate slurry onto the sediments, left them in place for a month, then retrieved them to determine survival of the cells. (Credit: MBARI)

(From WHOI / by Kate Madin) -- One proposed strategy to offset rising levels of greenhouse gases in our atmosphere is to capture carbon dioxide (CO_2) emissions from fossil-fuel-burning power plants and pump them into the ocean depths. Under the pressure of the deep sea, the CO_2 would remain sequestered, proponents say—out of the atmosphere, out of sight, and out of mind.

But some tiny but critical denizens of the seafloor might be out of luck.

Joan Bernhard, a geobiologist at Woods Hole Oceanographic Institution (WHOI), and colleagues at Monterey Bay Aquarium Research Institute (MBARI) investigated how one proposed geoengineering technique—direct injection of CO_2—might affect deep-sea life. Below a certain depth, the gas would form a dense mixture called a hydrate. Scientists think it would remain in depressions in the seafloor, not mixing with upper water layers and returning to the

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Sea-bed plan to store carbon

Storing carbon dioxide under the sea-bed could help to reduce global warming, according to US scientists.

CO2 would be pumped beneath the world's oceans

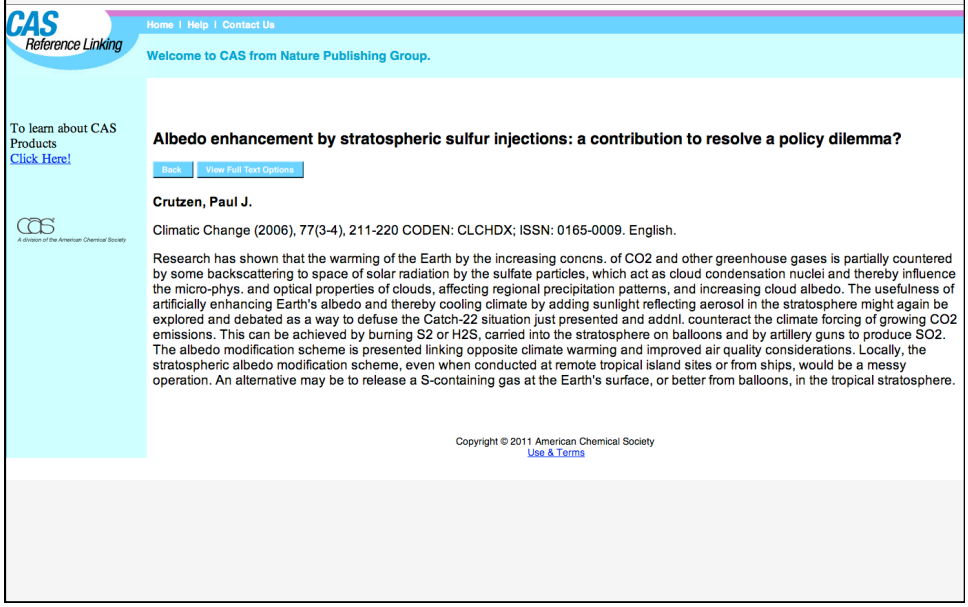
The proposals involve pumping the gas miles underground then injecting it under the sea floor.

There is enough space for almost unlimited carbon emissions, a US team reports in the Proceedings of the National Academy of Sciences.

Previous plans to store carbon under the sea have drawn criticism because of concerns over leakage and safety.

Supporters of the latest idea say that it overcomes these drawbacks and can be done with existing technology.

Not directly ocean-related



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Albedo enhancement by stratospheric sulfur injections: a contribution to resolve a policy dilemma?

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Crutzen, Paul J.

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Research has shown that the warming of the Earth by the increasing concns. of CO2 and other greenhouse gases is partially countered by some backscattering to space of solar radiation by the sulfate particles, which act as cloud condensation nuclei and thereby influence the micro-phys. and optical properties of clouds, affecting regional precipitation patterns, and increasing cloud albedo. The usefulness of artificially enhancing Earth's albedo and thereby cooling climate by adding sunlight reflecting aerosol in the stratosphere might again be explored and debated as a way to defuse the Catch-22 situation just presented and addnl. counteract the climate forcing of growing CO2 emissions. This can be achieved by burning S2 or H2S, carried into the stratosphere on balloons and by artillery guns to produce SO2. The albedo modification scheme is presented linking opposite climate warming and improved air quality considerations. Locally, the stratospheric albedo modification scheme, even when conducted at remote tropical island sites or from ships, would be a messy operation. An alternative may be to release a S-containing gas at the Earth's surface, or better from balloons, in the tropical stratosphere.